Ontario Industrial Energy

Demand Study

[misc. pubs]

Acres Consulting Services Limited

Ministry
of
Energy
Ontario

Acres Consulting Services Limited
Toronto, Canada

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ONTARIO INDUSTRIAL ENERGY DEMAND STUDY

Ontario

Ministry of
Energy

Queen's Park
Toronto Ontario

NOTE TO THE READER

This study is one of three studies commissioned by the Ministry on the subject of energy demand within the Province.

The other two studies are:

(1) Transportation Energy Demand Analysis, by Canadian Resourcecon Limited

(2) Residential and Commercial Energy Demand Analysis, by Informetrica Limited and Energy Research Group, Carleton University.

The purpose of these studies was to critically examine the structure of energy demand within the Province, to review the possible changes that could impact on future energy use patterns and to provide a means for projecting future energy demand based on the user's own view of socio-economic and technological developments in the future.

This report does not contain a forecast of future energy demand. The Industrial Energy Demand Study discusses the major energy consuming processes within 14 major subsectors.

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1 - INTRODUCTION

1.1 - Overview

The Ontario Industrial Energy Demand Study has been undertaken by Acres Consulting Services in two phases. Phase I, which resulted in the Overview Report of May, 1976, covered the historical industrial energy use picture in Ontario and formulated the basis on which industrial sectors would be isolated for analysis and the basis on which the industries would be surveyed for energy use data. Phase II, represented by completion of this report, was the execution of the industrial energy survey among 40 large energy using companies in Ontario and the model development for each of the selected sectors.

This report specifies the knowledge gained from the questionnaires and the way in which the quantitative data is handled in the model. Each section contains a description of the industrial processes and the ways in which energy is used in each process. There is a separate discussion of technological and conservation factors which affect energy use and an appraisal or estimate of the long-run effects of these variables on energy use. Finally, there is a description of the model derived for the industrial sector in question.

Within each industrial sector we have specified what we believe to be the most vital and important issues that may affect process demand for energy over the next 25 years. In some cases, these impacts have been estimated in quantitative terms while in others the detail required is beyond the scope of this particular study. Hence, we have simply stated that it is believed that certain

factors would have an influence on energy consumption in the future. Each individual sector could be the subject of a long and detailed study at least as comprehensive in terms of manpower inputs as this particular study.

As specified in the original terms of reference, each of these individual models could be calculated without the use of computer facilities. However, it is clear that while this is possible, it is a rather formidable and complex calculation task, particularly if one is undertaking a total scenario which changes the output and demand for energy in each of the separate sectors. Hand calculation is possible and probably more convenient to study the impacts of various technological or policy issues in one or two sectors, but certainly not if one is changing population or GNP forecasts of the future.

1.2 - Study Objectives

The objective of the study, as originally stated in the terms of reference, was to develop a set of workable forecasting tools for the industrial energy sector in Ontario. The emphasis and direction of the study was on developing the tools for forecasting and not developing a specific forecast. The casual reader should not expect to see a coherent energy forecast as such, but rather a pattern or structure for generating forecasts.

In addition to the above primary objective, it was clear from the beginning that an important secondary objective was the development of a much better understanding of the dynamics of energy use in industry. Consequently

considerable importance has been placed on descriptive background of the individual industry sectors and the complex relationship of energy to industrial process. This approach should assist in understanding the models and add to the confidence that interested observers can place in the models' results and also allow a future user to modify a single sector to meet new needs without a major reassessment of the industry.

1.3 - Study Approach

The methodology adopted for the industrial energy study can be loosely described as a bottom-up approach to an energy forecasting problem. Starting from a base of very limited assembled data on energy consumption in industry, the first priority was to assemble the relevant published material and establish quickly what was not available and would have to be obtained through a questionnaire. Once this was completed, the questionnaire was designed. Two approaches to the questionnaire design were considered, one being the standard format that was adopted and the other, a questionnaire designed specifically for each sector to be investigated. Had time and budget allowed, the latter approach would likely have yielded more complete results or in a few cases more relevant answers. However, many of the visits to corporations were undertaken by knowledgeable engineers and economists who were familiar with processes of the companies being interviewed and the specific questions relevant to a particular company or sector were usually explored in some detail. It is our judgment, therefore, that not too much has been lost by the use of the general questionnaire.

The methodology for covering the selected companies was to mail the questionnaire and letter of introduction, following up with a phone call and then a personal interview. In many cases an additional interview to verify the data and the interviewer's original write-up was also undertaken. This ensured confirmation of the interviewers' interpretation of the discussions and indeed in many cases resulted in corrections being made to both data and written statements on the companies involved. Numerous meetings were also held with industry association officials to obtain views on the overall trends and problems for particular industrial sectors.

Some questions arose regarding the viability of modeling individual sectors with respect to energy usage and also concerning the actual use that might be made of the developed models. The questions with respect to model viability usually arose from sources that have attempted their own internal energy models such as in the steel industry. The feeling was that the complexity and difficulty of developing such models within the format of our study time and budget could not possibly result in a useful model. This argument could be met with the counter argument that our purposes were somewhat different from the companies' modeling objectives in that we were not trying to represent exactly the operations of any one company. Despite this, some doubts remain.

Notwithstanding these isolated difficulties, the general response from industry was positive and helpful and allowed the study team to assemble most of the data and information that was requested in the questionnaire as well as additional information that became necessary as the model development proceeded.

TABLE 1.1

NET ENERGY CONSUMPTION BY INDUSTRY IN ONTARIO - 1973

Industry	Purchased Fuel[9]	Non-purchased & By-product Fuel	Feedstock	Total	Per Cent
		(Btu x 10^9)			
1. Abrasives	3,483	-	-	3,483	0.42
2. Agriculture[1]	34,145	-	-	34,145	4.15
3. Auto. Manufacture	12,570	-	-	12,570	1.53
4. Cement	22,327	-	-	22,327	2.72
5. Clay Products	5,107	-	-	5,107	0.62
6. Food and Beverages	38,130	-	-	38,130	4.64
7. Glass	12,169	-	-	12,169	1.48
8. Industrial Chemicals	79,683	-	22,461[7]	102,144	12.42
9. Iron Foundries[2]	18,233	-	2,232[8]	20,465	2.49
10. Iron and Steel	58,324	41,525[4]	127,990[8]	227,839	27.70
11. Lime	5,960	-	-	5,960	0.72
12. Mining, Smelting[3]	66,847	-	-	66,847	8.13
13. Petroleum Refining	6,826	60,741[5]	-	67,567	8.22
14. Pulp and Paper	73,697	16,154[6]	-	89,851	10.93
15. Other Manufacturing	113,746	-	-	113,746	13.83
Total	551,247	118,420	152,683	822,350	100.00

Source: Detailed Energy Demand and Supply in Canada, 57-207
Refined Petroleum Products, 45-204
Census of Manufacturing, various issues
General Review of the Mineral Industries, 26-201
Ontario Hydro

1 1974 data modifies to 1973 base.

2 Iron Foundries includes 14,718 x 10^9 Btu from Auto. parts manufacturers.

3 Mining, milling, smelting and refining consists of 32,427 x 10^9 Btu from mining and 34,418 x 10^9 Btu from smelting and refining.

4 Coke oven gas.

5 Fuel oil (34,479), fuel gas (25,775) and other (487).

6 Waste recovery - spent liquor and bark and hydraulic generation (based on 1972 data).

7 Fuel oil (727) and natural gas (21,734).

8 Coke.

9 Includes gasoline and L.P.G. which, except for agriculture, are not addressed in the model. (See Appendix C)

A few final comments are in order to provide at least one or two insights gained in preparing the study for the Ministry of Energy. First, it is apparent that this review of rather a large number of industries is insufficient to satisfy the concerns and interests of the industries involved. The decisions and actions of even the simplest of industries cannot be efficiently captured in a single relationship. At the same time, however, these criticisms from the industries should not be over-emphasized in that the effort expended on the study has revealed many of the vital and important characteristics of the decision-making processes as they affect energy in the specific industrial sectors.

Several appendices are included with this volume. Appendix A summarizes regression equations adopted for the output demand calculations and the dependent variables used in the equations. The historical values of the variables are also presented. Appendix B lists the conversion factors used in the study. Appendix C is a statistical summary by industry over the period 1964 to 1973. Data listed includes the principal statistics of the industry, fuel consumption and distribution by fuel type.

2 - MODELING APPROACH

2.1 - Introduction

The modeling exercise undertaken for this study is based loosely on the concepts of both regression and simulation. Standard multiple linear regression techniques are employed to forecast the demand for the products of the particular industries under study. Once determined, these figures then become input to the individual simulations of each industry to determine the means of supply and the energy requirements.

2.2 - Demand

For the purposes of this model, the demands on Ontario's industrial sector are expressed in terms of the output of each major industry. Thus, the cement industry is measured in tons of cement, the abrasives industry in terms of tons of its products: alumina oxide, silicon carbide and grinding wheels. Most industries have many more products than those which will be listed in this model. We have attempted, however, to isolate only those products which require large amounts of energy to produce and/or are considered to be the prime output of the industry in question.

The product or products selected are then matched to an external variable which is considered to be a driving force behind the industry. These driving or independent variables include such items as Gross National Product, Population or the output of a related industry.

The output figures are not rigidly linked to the external variables within the model. The links are presented as default conditions and are used to avoid a detailed marketing study of each of the 15 industrial sectors. Later scenarios may require that an alternative structure of the economy be postulated. This type of structural change can be accommodated by reassigning the links or imposing growth constraints on selected sectors of the economy.

The results of the regressions,[1] derived as the base case or some modification, represent the demands on the productive capacity of industry.

2.3 - Supply

A small simulation model is specified for each of the industries in this study. The model is based upon the production processes identified within the industry and is specifically oriented toward the energy inputs to the processes.

Each model consists of two stages. The first assigns the demand figures (as computed in section 2.2 above) to the specific processes of the industry. This assignment is based on current practice in the industry and corresponds to the base case or "business as usual condition". It is also tempered to a degree by the current capacity of each process as expressed in the model description.

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[1] In several cases the demand is specified as an exogenous variable which must be supplied by the user. These were used where the output derivation procedure was governed by a non-quantifiable element such as government policy.

The parameters used to apportion the total output to the processes are determined exogenously and thus can be modified, within limits, to reflect conditions of specific scenarios. These scenarios could show, for example, an older energy-inefficient process being phased out and a more energy-efficient one replacing it over a forecast period. The output data so calculated is formatted in a column matrix, one row of each process identified in the industry model.

The second stage matches the assigned process demand to a per unit energy matrix. This matrix contains the fuel requirements -- coal, fuel oil, natural gas and electricity -- to produce one unit of output.[1] The coefficient for each energy form embodies the current technological levels of each process. Where new technology is anticipated it has been included as a new process, thus a technological change is not reflected as a change in the coefficient but rather as a movement to another coefficient in the matrix. The format of the matrix is such that there is one row for each process and one column for each energy form. In most industrial sectors there are four columns one for each of fuel oil, natural gas, coal and electricity. Additional columns have been provided where necessary for such items as feedstocks and steam.

The product of the per unit energy requirements matrix and the demand column matrix is the total demand for energy by energy form.

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[1] While gasoline and L.P.G. are included in the summary tables and totals by industrial sector (Table 1.1 and Appendix C), they are not explicitly identified in the industry models with the exception of agriculture. Consumption of these fuels in wholly industrial processes (excluding, for example, transportation of goods) is minimal and could not be considered at length. Total consumption represents 2.28 per cent of total industrial energy consumption (p. C-18).

2.4 - Summary

In summary, the methodology is:

- Estimate total industry demand through multiple linear regression, simulation or trend analysis and the driving variables of the industry.

  The selection of output figures to suit the base data requirements is tempered a great deal by the availability of data. Often only national figures or figures which included undesired information are available. These have been modified through consultation with the industry or knowledge of certain aspects of the industrial structure to obtain provincial data consistent with the needs of the model.

- Assign demand to the various production processes.

  Assignment to the various production processes is based on technological requirements, knowledge of existing capacity by process and current industry practice. The most common assumption made in this section and one which was required in the absence of detailed industry by industry records was that all facilities would be operating at the same percentage of capacity.

- Compute total energy consumption using the assigned demands and per unit consumption figures.

  Per unit energy consumption figures were provided to a large degree in the survey conducted early in this study. This information was supplemented by the literature and in-house expertise.

The assumptions, base data and parametric values are listed and described in each industrial sub-sector.

3 - INDUSTRY MODELS

3.1 - Abrasives

3.1.1 - Industry Overview - Energy Use

During 1973 the producers of crude abrasives and abrasive products in Ontario consumed 3,483 x 10^9 Btu of energy. While this figure represents less than 0.5 per cent of total industrial energy in the province, the industry is significant because it is one of the more energy-intensive industries. This statement holds for all three measures of intensity: Btu/employee, Btu/dollar of value added or Btu/dollar of shipments. Another, perhaps more significant reason for a separate analysis of abrasives is that electricity is a large portion of its purchased energy.

Other energy sources for the industry are fuel oil and natural gas. Petroleum coke is also utilized in the abrasives manufacturing processes,[1] but it is considered to be a material input rather than an energy source.

3.1.2 - Industry Overview - Markets

Ontario is the world's leading producer of artificial abrasives, supplying 70 per cent of the world production of alumina abrasives and more than 50 per cent of the silicon carbide products. Abrasives and abrasive products find their greatest use in metal working and machining industries, notably in the automotive and aerospace sectors. However, grinding is a time-consuming and thereby expensive operation and is replaced with cheaper processes

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[1] The industry in Canada consumed some 139,733 tons of petroleum coke in 1973 (Statistics Canada 44-202).

wherever possible. Such products as extruded aluminum sections, aluminum die castings and molded plastics are finding increasing uses as replacements for grinding operations. This results in a declining per unit demand for abrasives in these industries. Extensive research to find new products and market areas based on the abrasive materials hopefully can compensate for much of the reduced demand in the traditional markets.

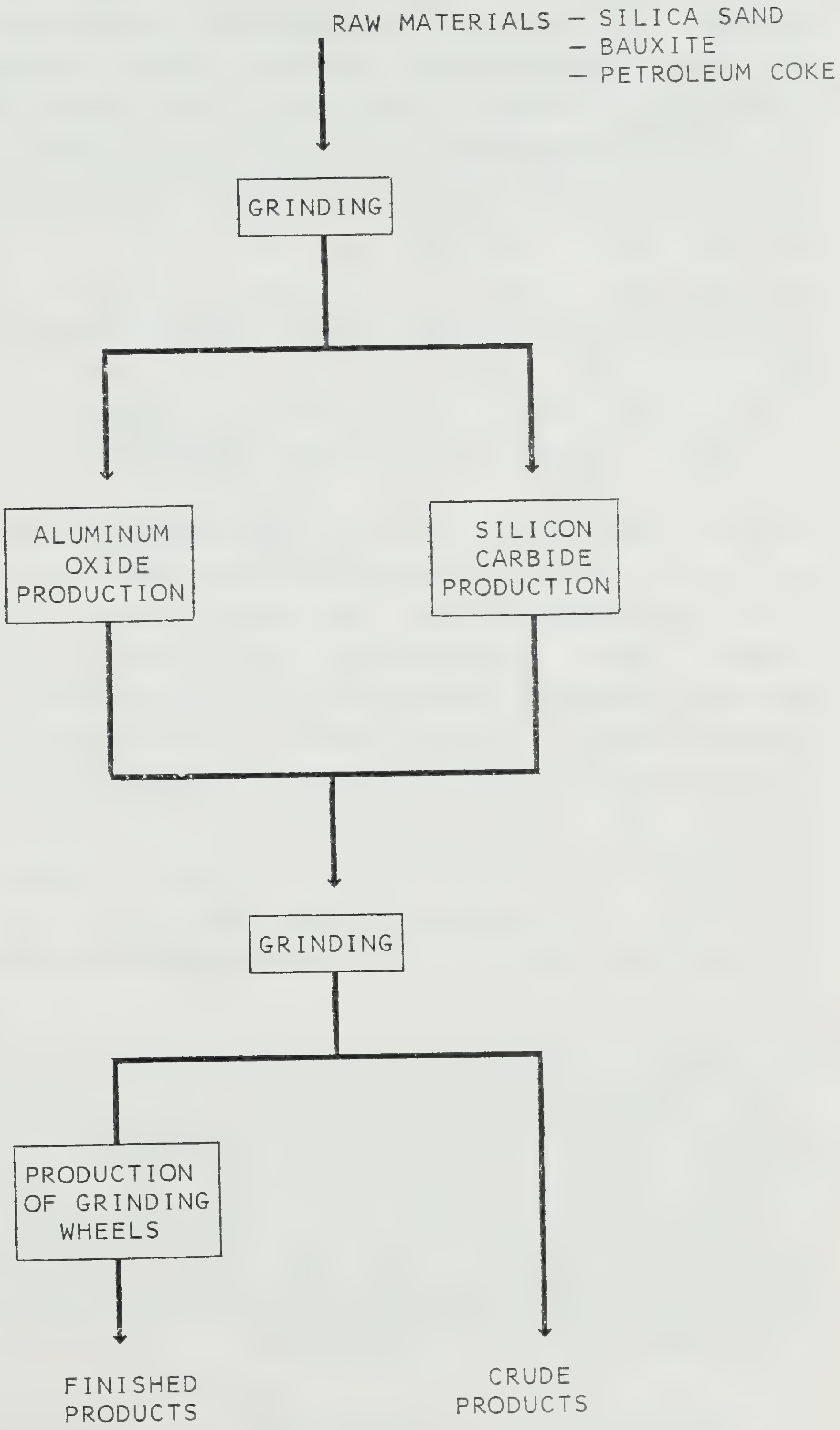
Most of the artificial grain produced in Ontario is exported in its crude form to be used in the production of grinding wheels. Only a small percentage is fused into grinding wheels within the province.

3.1.3 - Production Process

The industry is dominated by the production of two products, aluminum oxide (Al_2O_3) and silicon carbide (SiC). The products are differentiated by raw material mix as much as by production process. Al_2O_3 is best suited to grinding of heat treated steels. SiC is used to grind hard and brittle materials such as glass, ceramics and drilled iron castings.

Aluminum oxide is produced in an electric arc furnace, either of a batch or a continuous melt type, the latter being of a similar construction to steel melting furnaces. The furnace charge is a mixture of bauxite, petroleum coke and iron. Electrical power, provided by the electrodes in the furnace, fuses the alumina and reduces the silica in the bauxite to silicon which unites with the iron to form the by-product ferrosilicon. Electricity is the only fuel consumed in the process.

PRODUCTION PROCESS
ABRASIVES



Silicon carbide is produced in an electric resistance furnace from a charge of 60 per cent silica sand and 40 per cent petroleum coke. Electric power, provided by graphite electrodes at each end of the furnace bed, raises the temperature of the charge to 2400°C at which point the carbon and silica combine to form the finished product.

Both processes take about a week to produce the desired products, after which they are crushed and ground to form abrasive grain for the market. Electricity provides the power for both crushing and grinding.

Most of the abrasive grain is eventually consumed in the production of grinding wheels. The grain is mixed with a suitable bonding agent and heated slowly to approximately 2300°C. Natural gas is the preferred energy form in this process. Gas-fired kilns enhance pollution control and product quality. Fuel oil is available as a stand-by fuel in case of an interruption in the supply of natural gas. There is a possibility that electricity may be adopted for use on new kiln equipment because of ease of control, environmental advantages and product quality. No definite plans in this regard have been announced.

The final activity of the industry is the production of coated abrasive products, e.g. sandpaper. Abrasives, both natural, garnet, flint and emery, and artificial, aluminum oxide and silicon carbides, are glued to a paper or cloth backing and dried in a gas-fired oven. Small amounts of electricity are also used in this process. The volume of gas consumed in this process was too small to warrant separate consideration.

3.1.4 - Energy Consumption

Energy consumption is essentially in two forms: electricity and natural gas. It is estimated by the industry that 93 per cent of the electrical load is used in the furnaces, the remainder is motor load and other uses such as lighting. Some 67 per cent of the natural gas is used for process heat, the remaining 33 per cent is for space heating.[1] Based on 1973 data,[1] the components of total energy demand in the industry are as follows:

Process:	
Electric furnace	84.2%
Process heat (gas)	6.4
Motor load	5.9
Space heating	3.1
Other (lighting)	0.4
	100.0%

Fuel oil consumption is not included here as it is only used as stand-by fuel in the event of a curtailment of natural gas supplies to the grinding wheel process.

3.1.5 - The Future Outlook

Markets

The industry overview outlined the changing patterns of market in abrasives industry and the pressure on the industry of substitution of plastics and aluminum extrusions for ground and polished metal. This has resulted in relatively slow growth of just over 2 per cent per year. In the longer term future, such pressures are likely to persist thus leading to the conclusion that

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[1] Acres Survey and Ontario Hydro Study, Energy Use in the Abrasives Industry in Ontario, May 1974.

slow growth will continue. The heavy reliance of the industry on cheap electricity, the raison d'etre for the industry's existence in Ontario in the first place, could leave the production of abrasives in Ontario vulnerable to new production overseas in cheaper energy regions. In the longer run beyond 1986, the scenario of no-growth or even decline in Ontario production is probably not unreasonable.

Conservation

The industry has definite energy conservation programs. These programs are focused in two areas. The first deals with housekeeping which, in turn, is a function of scheduling and operating procedures. This program is expected to save 10 to 15 per cent on current energy consumption and should be achieved by 1985. The second is aimed at finding an abrasive material which requires less energy to produce, either through additives to current materials or new materials. No estimate of consumption or savings was available in this area, nor is there a clearly definable possibility of achieving results in this research. The long-term outlook is therefore predicated on continued production of present abrasive products.

Technology

Current research indicates there are no viable alternatives to the electric furnace in abrasives manufacture within the 25-year time frame of this study. The only foreseeable technological change, as mentioned above, is directed toward reducing energy input by modifying the raw materials charged to the furnace. In addition, electrical energy may be adopted on replacement equipment in the finishing processes to enhance control and

product quality and to benefit from the environmental advantages of electricity. This could push the electrical demand up to about 95 per cent of energy requirements in the industry by 1990 and would result in space heating as the only non-electric energy demand in the industry.[1]

3.1.6 - Industry Model

Five energy-related processes have been identified in the abrasives industry as:

- Aluminum oxide production,
- Silicon carbide production,
- Crushing and grinding,
- Fusing of grinding wheels, and
- Utilities

The demand for abrasive products over the past decade has been subject to wide fluctuations reflecting the demand in its major market area: automobile manufacturing. Other markets have been developed in the ceramics, glass and iron and steel industries and include the use of various by-products, e.g. ferrosilicon. The largest export market for Canadian abrasive products is in the United States. Total demand has been related to the total production of automobiles in North America.

The model is concerned with the production of three abrasive products: aluminum oxide (Al_2O_3), silicon carbide (SiC) and grinding wheels made from these two crude

[1] Space heating is currently slightly over 3 per cent of total energy demand.

products. Canadian output of crude abrasive products, expressed in tons, was available for all years,[1] however Ontario production was available for 1971 only.[2] The output of grinding wheels was not listed and was calculated as the total tons of SiC and Al_2O_3 used as input to the production of the wheels.

Based on the relationships expressed in 1971, it was assumed that 45 per cent of the Canadian output of SiC, 90 per cent of the production of Al_2O_3 and virtually all of the grinding wheels were from Ontario plants.

In order to substantiate this assumption, the value of shipments for Ontario derived from the assumption was compared to the actual value for the province. The estimates were consistently over 90 per cent of the actual figures.

The estimated output figures revealed that an average of 74.5 per cent of the total provincial output was Al_2O_3, the remainder was SiC. In addition, the tons of crude abrasives used to produce grinding wheels represented an average of 3.2 per cent of the total output of these grains. We have found no data which would indicate a future change in either of these proportions.

Per unit energy consumption was obtained from the survey and confirmed in the literature search. Earlier in the decade the industry used coal, fuel oil and natural gas for the fusing operations and space heating. Current practice uses, almost exclusively, natural gas with small amounts of fuel oil. Electricity is used in all of

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[1] Statistics Canada - 44-202

[2] Ontario Hydro Study.

the processes identified in the model: Al_2O_3 production, SiC production, grinding of finished products and of raw materials, fusing of grinding wheels and plant utilities. Natural gas is consumed only in the fusing operations and for utilities. Utilities include space heating, electrical motive power and gas-fired ovens for ferro-carbon production.

The final characteristic of note in this section is that most of the crude abrasive output is exported to the United States. Finished products such as abrasive wheels, paper and cloth have traditionally been for domestic use. Recent data, however, indicates that exports of finished products have increased dramatically. If this trend were to continue and more finished products were to be produced domestically, increases in energy consumption in the finishing processes could be expected. The form of energy consumed -- natural gas or electricity -- will depend upon the investment plans for new equipment in this process as discussed earlier. (Section 3.1.5 - Technology)

Demand for total abrasive products in tons is calculated as:

(1.1) ... $Q_t = 50{,}205 + 0.015\ (AUTOP_{t-1})$

where, Q_t is Ontario abrasives industry output in tons,

$AUTOP_{t-1}$ is total North American auto production, lagged one year.

Total demand as computed above will include the demand in tons of the two major crude abrasive materials, Al_2O_3 and SiC. As energy consumption per unit output is different between the two, it is necessary to apportion the

total demand.

(1.2) ... $q_1 = p_1 \; Q_t$

(1.3) ... $q_2 = (1 - p_1) \; Q_t$

where p_1 is the proportion of the total demand to be met by aluminum oxide. This parameter as discussed earlier has a current value of 0.745. Thus q_1 is the quantity of aluminum oxide and q_2 the quantity of silicon carbide produced.

The final major energy consuming process is the production of grinding wheels. The output is related to the total demand of the industry, thus the quantity of grinding wheels produced is expressed as a proportion of (p_2) of total demand:

(1.4) ... $q_3 = p_2 \; Q_t$

Historical values for these variables are provided in Table 3.1a.

Currently no allowance has been made in the model for energy consumption in the production of coated abrasives, e.g. paper and cloth abrasives, because this component was small in both total output and energy intensity. If either of these conditions were to change, an additional quantity figure, q_4, would be required.

The average weight of the automobile as it relates to the amount of iron and steel in the vehicles will have an effect upon demand for abrasive products. No data was readily available with which to test this relationship. In an effort to meet government mileage requirements in their products, automobile manufacturers have been replacing heavy components, usually made of iron and steel, with lighter molded plastics and cast aluminum products

which do not require abrasives in processing. This clearly results in reduced demand for the products of the abrasives industry. The relationship between automobile weight and abrasive demand should be investigated and considered in the basic demand equation (1.1) at some future date.

Three issues affecting potential energy consumption in the production processes were identified as the production mix of Al_2O_3 versus SiC, the development of new products requiring additional (or reduced) processing and the inclusion of additives to the raw materials to reduce energy input. No assessment of changed energy input was available.

Per unit energy requirements were obtained from the Acres' survey, the Ontario Hydro Study and from other literature. The data are listed in Table 3.1b as millions of Btu per ton of output as measured by the relevant variable. Thus, the production of one ton of aluminum oxide currently requires 8,530,000 Btu of electricity.

TABLE 3.1a

VARIABLES IN OUTPUT FORECASTING EQUATION

Year (t)	Dependent Variable (Q_t)[1]	Independent Variable ($AUTOP_{t-1}$)[2]
1964	171,950	8,162,453
1965	196,705	8,293,600
1966	214,283	9,996,586
1967	179,474	9,292,381
1968	176,190	8,150,848
1969	196,578	9,714,007
1970	181,968	9,260,490
1971	158,607	7,488,310
1972	191,089	9,679,645
1973	207,338	9,982,377

[1] Abrasives, Ontario output in tons (total of aluminum oxide and silicon carbide)

[2] Motor Vehicle Manufacturers Association, number of passenger vehicles produced in North America lagged one year.

TABLE 3.1a (cont'd)

ESTIMATES OF ONTARIO ABRASIVES OUTPUT
1964 - 1973

(tons)

Year	Total Output (Q_t)	Al_2O_3[1]	SiC[2]	Grinding Wheels[3]	Al_2O_3 as % of Total[4] (P_1)	Grinding Wheels as % of Total[5] (P_2)
1964	171,950	133,505	38,445	6,513	77.6	3.8
1965	196,705	152,360	44,345	7,809	77.5	4.0
1966	214,283	165,525	48,758	5,672	77.2	2.6
1967	179,474	136,179	43,295	5,815	75.9	3.2
1968	176,190	127,062	49,128	5,230	72.1	3.0
1969	196,578	147,889	48,689	5,461	75.2	2.8
1970	181,968	130,324	51,644	5,803	71.6	3.2
1971	158,607	112,039	46,568	5,125	70.6	3.2
1972	191,089	139,425	51,664	5,658	73.0	4.0
1973	207,338	154,112	53,226	7,177	74.3	3.5
Average 1964-73	-	-	-	-	74.5	3.2

Source: Statistics Canada, 44-202.
Acres.

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[1] 90 per cent of total Canadian production of Al_2O_3.

[2] 45 per cent of total Canadian production of SiC.

[3] 100 per cent of total Canadian production of SiC and Al_2O_3.

[4] Average of 74.5 per cent used in model.

[5] Average of 3.2 per cent used in model.

TABLE 3.1b

PER UNIT ENERGY REQUIREMENTS
ABRASIVES INDUSTRY

(Btu x 10^6/unit)[4]

Production Process (Variable)	Energy Form: Fuel Oil	Natural Gas	Coal	Electricity
Al_2O_3 production (q_1)	-	-	-	8.53[1]
SiC production (q_2)	-	-	-	24.57[1]
Grinding (Q_t)	-	-	-	0.19[2]
Fusing grinding wheels (q_3)	-	14.52[3]	-	3.79[3]
Utilities (Q_t)	-[5]	1.05[1]	-	1.85[1]

[1] Acres Survey and Ontario Hydro Study.

[2] Taggart, Handbook of Mineral Dressing (75 hp-hr/ton).

[3] Acres survey.

[4] Units are tons of output of each process.

[5] The primary use of fuel oil is reported to be as a standby fuel for natural gas in the fusing operation. No specific data was available for this study; however, based on 1973 aggregates the coefficient when included as a utility process is 0.35 Btu x 10^6/ton of abrasives.

3.2 - Agriculture

3.2.1 - Industry Overview - Energy Use

The direct utilization of energy in Ontario's agricultural production is considerable, both in terms of total quantities consumed and as a percentage of the total dollar value of output. Expenditures on energy represent 6.4 per cent of total operating expenses. In addition, the consumption of energy through indirect means by the application of fertilizers and insecticides as well as in capital equipment is substantial. In fact, efforts directed towards increased energy efficiency in the production of these indirect inputs or the introduction of less energy-intensive substitutes would seem to offer a far greater impact on fuel consumption in Ontario than programs aimed at reducing the level of direct energy inputs within the agricultural sector.

Approximately 34.1 x 10^{12} Btu were consumed in agricultural production in 1974, comprising 4.15 per cent of Ontario's total industrial energy for that year. The estimated breakdown by fuel is:

Gasoline	33%
Diesel	24%
Natural Gas	19%
L.P.G.	6%
Fuel Oil	10%
Electricity	8%

Source: Derived from R.G. Winfield, Energy for Food Production in Ontario, 1974.

3.2.2 - Industry Overview - Markets

Demand for agricultural produce in Ontario has continued to rise with increasing population in the province. This trend is expected to continue with the agricultural sector becoming increasingly oriented toward serving the growing provincial urban centres rather than national or international markets. The redirection to provincial markets will be reinforced by increasing transportation costs in Canada and the United States which, along with continued shortages in world markets can be expected to result in improved price competitiveness of locally produced foodstuffs. Therefore, outside of any cyclical trend in economic activity, expansion of both physical outputs and dollar value of receipts may be expected to grow at 3.5 per cent per year for the decade in line with projected rates of urban growth in the province.

Within the sector itself, prospects for particular commodities are less clear. The quantity produced of many goods such as tobacco, eggs, and milk are highly sensitive to governmental programs as well as consumer preference. However, allowing that there will be no major shifts in provincial and federal agricultural programs, it may be safe to assume that no important agricultural goods will suffer significant weakening in demand, thereby keeping the overall mix of outputs constant.

3.2.3 - Production Process and Energy Consumption

There are three major functions in which energy is consumed. First, there are operation of internal combustion engines used primarily as sources of motive power for soil

manipulation. Second are burner operations for drying and space heating. As far as possible, operation of private automobiles, domestic heating and lighting have been excluded from consideration in all data presented. A final category of miscellaneous has been added to capture utilization of energy not covered by other functions. The estimated percentage distribution by function and process is:

Function	Process	
Engine operation	- Motive power	57%
Burner operation	- Grain drying	7%
	- Space heating:	
	(Brooding	4%
	(Greenhouse heating	10%
	(Tobacco curing	13%
Miscellaneous		9%
		100%

Source: Derived from R.G. Winfield, 1974.

Of the six energy sources used widely in agriculture, gasoline, diesel and electricity appear to be essential to farm operations. Without an alternative to conventional powered trucks and tractors, no significant changes in consumption can be anticipated. Equally, the use of electricity to power pumps and lighting is indispensable especially in the dairy industry. Shortages of these fuels or sudden price adjustments, because of their vital nature, could seriously disrupt agricultural production.

In the case of natural gas, fuel oil and L.P.G., greater ability to substitute among the fuels consumed is evident.

Therefore, agricultural production may not be significantly affected by changes in pricing or availability. Given appropriate pricing and capital availability, electricity could conceivably be used to displace considerable quantities of gas, oil and L.P.G. now consumed in space heating operations.

3.2.4 - The Future Outlook

Within the agricultural sector, opportunities for energy savings without major capital expenditures are outlined below as a percentage of current energy consumption by process. These savings will likely be realized as much by increased relative prices for the fuels concerned as by incentives (tax subsidy, etc.) to encourage conservation:

Motive Power	
Improved engine maintenance	5%
More efficient engine operation	10%
	15%
Grain Drying	
Greater open air drying	10%
Tobacco Curing	
Improved design, insulation and maintenance of kilns	15%
Greenhouse Heating	
Improved design, insulation and maintenance of greenhouses	30%
Brooding	
Improved design, insulation and maintenance of brooding buildings	15%

A program aimed at exploring other areas of farm operation leading towards greater fuel efficiency and the publication of information available on energy conservation would increase the rate at which the savings occur.

If major research and capital expenditures are to be made, the introduction of improved grain dryers and burners for greenhouse heating are areas which presently offer the greatest possibility of success. Improved high temperature dryers may result in 30 per cent savings on per unit output fuel consumption. The Air Swirl Generator currently being developed by the Department of Energy, Mines and Resources could result in a 10 per cent reduction in fuel consumption for greenhouse operators. Further utilization of waste heat for greenhouse, kiln and brooder heating may also prove to be economically and environmentally sound concepts.

Of more significance to overall energy conservation in the province is the substitution of plant and animal waste or suitably treated urban wastes for synthetic nitrogenous fertilizers. Such a substitution, though requiring far greater expenditures by both private operators and government agencies, would induce a considerable reduction in the demand for natural gas as a feedstock and process fuel for ammonia production; ammonia being the major intermediate input into fertilizer production.

No less important is the initiation of an effective land use policy at the regional level to preserve soils of higher productivity from the encroachment of non-agricultural uses. This would prevent the migration of farming to marginal lands which would raise fuel and fertilizer inputs and would ensure proximity to major markets thus keeping transportation costs to a minimum.

3.2.5 - Industry Model

Seven processes have been isolated in the agriculture industry:

- Motive power
- Grain drying
- Brooding
- Tobacco curing
- Greenhouse heating (natural gas)
- Greenhouse heating (fuel oil)
- Miscellaneous.

Data for agricultural energy consumption is, at best, scarce. It is usually grouped with residential or commercial sectors or completely ignored. (In one publication, Statistics Canada lists expenditures for telephone service and electricity together.) Two recent papers, based on 1974 data, provided the core of the energy consumption relationships in this study.[1]

Motive power is expressed in terms of the total number of acres under field crops, fruit, vegetables and improved pasturage. Total acreage was not forecast but rather is left as an exogenous variable to the model. Historical values are provided in Table 3.2a. Therefore:

(2.1) ... ACRES = exogenous variable.

Grain drying is measured in terms of the number of bushels of all grain crops which require drying. Winfield assumed that corn makes up 90 per cent of the total and

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[1] Winfield, R.G., Energy for Food Production in Ontario.
Southwell, P.H., Energy in Perspective

estimated that 85 per cent of the corn crop was dried. No explicit forecast equation is provided in this study. Projection of future grain output will be exogenous to the model and will be based on projections of yield, total acres and acres devoted to grain. Historical data are provided in Table 3.2a. Total production, therefore, is:

(2.2) ... q_2 = exogenous variable.

Brooding is measured in terms of the total number of hens, chickens, commercial broilers, turkeys, ducks and geese produced and computed in terms of provincial population.

(2.3) ... $q_3 = -86,826 + 22.8\ (POP)$

Tobacco output is governed by the number of acres dedicated to the production of tobacco. This, in turn, is controlled by a marketing board structure which sets an annual quota for production and conducts a sealed bid system to allocate this quota among the farms. For the purposes of this model, the measure of tobacco output is considered to be exogenous and is expressed in pounds. Historical values are provided in Table 3.2a.

(2.4) ... q_4 = exogenous variable.

The total greenhouse area used for food and ornamental flower production is expressed in thousands of square feet and is computed in terms of provincial population.

(2.5) ... $q_g = -17,048 + 5.37\ (POP)$

The greenhouse process is subject to high substitutability between natural gas and fuel oil for heating. This

substitution is simulated using a parameter to assign production to one fuel or the other.

(2.6) ... $q_5 = p_1 \, q_g$

(2.7) ... $q_6 = (1 - p_1) \, q_g$, where p_1 is the proportion of total area assigned to natural gas heating.

Data was not available for the area of greenhouse production heated by natural gas versus fuel oil. This was estimated in the Winfield study for 1974 to be 73 per cent natural gas, 27 per cent fuel oil. The substitutability of these fuels is reflected in the 1973 estimates of 18 per cent and 82 per cent for natural gas and fuel oil respectively.

The miscellaneous process category represents all other energy consuming operations on the farm, lighting (excluding residential), milking machines, electric fencing, etc. The process is measured in terms of constant dollar farm cash receipts.

(2.8) ... $q_7 = 529{,}782 + 72.7 \text{ (POP)}$.

In summary,

ACRES is total acres of improved land,

q_2 is total output, in bushels, of grain crops requiring drying,

q_3 is total number of poultry birds produced,

q_4 is tobacco quota, given, in pounds,

q_g is area available for greenhouse production,

q_7 is farm cash receipts, in 1961 dollars,

POP is provincial population, in thousands.

Agriculture is the only industry in this model which specifies consumption of gasoline and diesel oil for motive power. These were included because of the large quantities of fuel consumed in the process and under the assumption that they would not be included in the transportation sector model.

For purposes of this study it is assumed that natural gas is the only fuel used in grain drying. In practice propane is also consumed as many farms and elevators do not have a natural gas supply. While greenhouse and tobacco curing operations are able to substitute fuel oil for natural gas and vice versa, according to the literature no such ability was granted the grain drying operation. Windfield estimates that half of the greenhouse area in Essex County was switched from fuel oil to natural gas in one year. The fact that it could be switched back to oil within one day, highlights the substitutability in this process.

Per unit energy consumption data were computed essentially from the Windfield study and are listed in Table 3.2b.

TABLE 3.2a

AGRICULTURAL PRODUCTION

Year	Independent Variable Population (POP)	Dependent Variables Birds (q_3)	 Green-house (q_g)	 Farm Cash Receipts (q_7)	Exogenous Variable Tobacco (q_4)
1964	6,631.0	65,560	16,640	1,014,620	143,035
1965	6,788.0	69,113	18,647	1,000,791	158,810
1966	6,960.9	73,801	20,923	1,029,795	220,736
1967	7,127.0	75,099	22,580	1,051,852	201,074
1968	7,262.0	75,092	23,385	1,070,896	204,256
1969	7,385.0	82,639	23,882	1,071,316	230,340
1970	7,551.0	88,328	22,832	1,098,803	202,301
1971	7,703.1	89,328	25,452	1,103,528	204,624
1972	7,833.9	91,248	24,158	1,131,920	171,044
1973	7,938.9	96,233	23,819	1,046,152	236,240

where, q_3 is in thousands of birds, Statistics Canada 23-202

q_4 is in thousands of pounds, green weight, Statistics Canada 22-205

q_g is in thousands of square feet, Stat. Canada 22-202

q_7 is in thousands of 1961 dollars, Stat. Canada 21-201

POP is provincial population, in thousands, TEIGA.

TABLE 3.2a (cont'd)

EXOGENOUS VARIABLES - ACREAGE [1]

(acres)

Year	Total Acres	Field Crops: Tobacco[2]	Field Crops: Grain Corn	Field Crops: Other	Fruit & Vegetables	Improved Pasture
1964	11,009,771	76,267	650,000	6,993,533	189,971	3,100,000
1965	10,995,994	89,220	740,000	6,875,450	191,324	3,100,000
1966	11,042,096	120,561	786,000	7,036,874	162,968	2,935,693
1967	11,070,018	130,871	850,000	7,096,019	193,128	2,800,000
1968	10,715,827	123,968	930,000	6,772,501	199,358	2,690,000
1969	10,401,211	120,130	935,000	6,624,370	191,711	2,530,000
1970	10,271,346	93,888	1,125,000	6,453,481	188,977	2,410,000
1971	10,080,495	82,626	1,263,000	6,210,772	188,097	2,336,000
1972	10,014,468	88,663	1,200,000	6,248,337	237,468	2,240,000
1973	10,120,789	106,314	1,175,000	6,386,509	248,966	2,204,000

Source: Ontario Agricultural Statistics.

[1] Crop year begins Aug. 1, thus 1964 output is for August 1, 1964 to July 31, 1965 (Statistics Canada 21-516)

[2] Harvested acre crop year ending September 30.

TABLE 3.2a (cont'd)

EXOGENOUS VARIABLES - GRAIN OUTPUT
(000 bushels)

Year[1]	Total	Grain Corn	Wheat	Grain Oats	Barley	Other[2]
1964	196,225	52,715	18,685	80,864	6,342	45,336
1965	207,210	59,348	13,723	77,816	9,594	49,998
1966	202,201	65,081	15,827	59,243	11,236	42,538
1967	200,301	72,250	15,844	57,942	13,196	47,446
1968	214,028	78,957	15,208	57,312	16,320	53,581
1969	208,039	70,218	14,570	42,240	15,750	51,922
1970	208,915	95,625	15,854	38,994	17,353	55,304
1971	227,075	102,303	14,515	35,190	20,844	58,168
1972	220,102	91,200	16,307	30,149	18,338	53,190
1973	209,563	101,050	15,172	25,596	17,255	50,870
1974	201,923	90,200	19,370	23,415	15,470	45,449

Source: Handbook of Agricultural Statistics (Statistics Canada 21-516)

[1] Crop year begins August 1, thus 1964 output is for August 1, 1964 to July 31, 1965.

[2] Rye, buckwheat, mixed grains.

TABLE 3.2b

PER UNIT ENERGY REQUIREMENTS
AGRICULTURE

(Btu x 10^6/unit)

Production Process (variable)	Unit	Energy Form: Fuel Oil	Natural Gas	Coal	Electricity	Gasoline	Diesel Oil
Motive power (q_1)	acres	-	-	-	-	.93	.69
Grain drying (q_2)	000 bu	-	25.3	-	-	-	-
Brooding (q_3)	000 birds	2.5	7.4	-	2.5	-	-
Tobacco curing (q_4)	000 lbs	7.2	8.1	-	-	-	-
Greenhouse heat (q_5)	000 sq ft	-	171.9[1]	-	-	-	-
Greenhouse heat (q_6)	000 sq ft	171.9[1]	-	-	-	-	-
Misc. (q_7)	000 $	.1	.1	-	1.9	-	-

Source: Winfield, R.G., Energy for Food Production in Ontario.
Acres' estimates.

1 Winfield estimates 350 acres of food production under glass and plastic in 1974. Variables q_5 and q_6 include ornamental flower production and assume the same per square foot heat requirement as food.

3.3 - Automobile Manufacturing

3.3.1 - Industry Overview - Energy Use

The manufacture of motor vehicles in Ontario consumed a total of 12.6×10^{12} Btu of energy in 1973. However, the requirements in relation to Btu per employee, Btu per dollar of goods shipped and Btu per dollar of value added were moderate. The rankings for these measures when compared to other industries covered in the study were nineteenth, thirty-first, and twenty-sixth respectively.[1] The principal fuels supplying energy to the industry in 1973 were coal (16.6%), fuel oil (25.7%), natural gas (34.6%) and electricity (19.6%).

3.3.2 - Industry Overview - Markets

Automobiles and trucks manufactured in Ontario are marketed throughout North America. Overseas markets at this time are not important. In the period 1964 to 1973 the market for products from this industry expanded at a very rapid rate, the constant dollar value of goods shipped growing at an average of 10.4 per cent per year while unit output expanded at 7.6 per cent per year. However, with the onset of higher fuel costs and reduced consumer spending in 1974-75, the number of motor vehicles produced in Ontario contracted to levels characteristic of the late 1960's and the expansion of productive capacity ceased.

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[1] A total of 34 industries were considered in the first phase of this study.

3.3.3 - Production Process

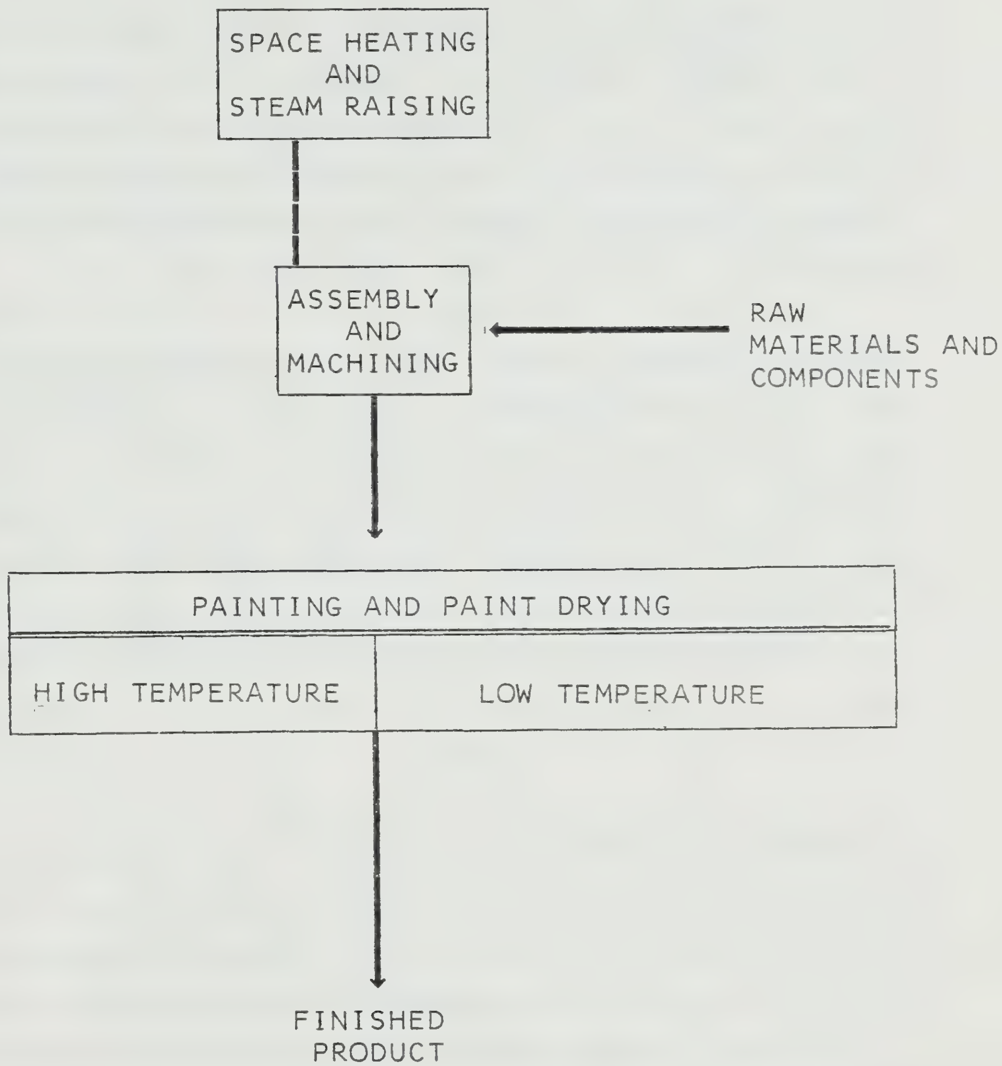
The activities undertaken in the motor vehicle manufacturing sector may be more aptly described as motor vehicle assembly. No fabrication of basic parts is undertaken within the sector. Instead, the components required are produced by establishments outside of the sector, the parts being collected for final assembly at locations which are central to market areas.

Within the sector itself, plant operations consist principally of the sequential addition of modules. Some preparation for assembly such as grinding, welding, fitting and most importantly painting, occurs at this stage. Basic components are delivered to tributary assembly lines where they are used to construct sub-assemblies such as completed motors, chassis and other units. The modular components are in turn brought to central conveyor lines where final assembly of the various model types takes place. When assembly is completed, the vehicles are tested and either added temporarily to inventory or shipped immediately to a dealership.

3.3.4 - Energy Consumption

Coal is used in this sector to raise steam for space heating and minor process heat. Total consumption of coal has been decreasing as its function has been assumed by fuel oil and natural gas. The reasons for this change are common throughout the industry, oil and gas are easier to handle and require less elaborate pollution control equipment. In current operations fuel oil is used for the same processes as coal -- firing boilers for steam and minor process heat.

PRODUCTION PROCESS
AUTOMOBILE MANUFACTURE



Natural gas usage is split between space heating, high temperature paint drying and direct process heat such as soldering. Based on our survey, approximately 40 per cent of the natural gas is consumed in the paint drying process. In most plants propane is available as a standby for natural gas in case of interruptions in service. Propane is used as most facilities currently using gas are not equipped to handle either fuel oil or electricity as energy sources.

Electrical power is used throughout assembly plants for a wide variety of purposes. Conveyors, hand tools, lighting, welding units and precipitators for air cleaners all depend on electricity. Unfortunately, a detailed breakdown of the distribution of total consumption over the various applications is not available. In the immediate future, electricity will remain the primary source of power on the shop floor while its use for paint application and baking will expand.

At present, considerable opportunities exist for substitution among natural gas, fuel oil and L.P.G. Further, some adaptability between electrical power and natural gas for paint drying and baking operations is evident. However, in the case of electrical usage there is little opportunity in the immediate or long-term to introduce alternate energy sources. Therefore, with the single exception of electricity, motor vehicle manufacturers should not experience any unusual disruption of plant operations if short falls in the supply of a particular fuel arise.

3.3.5 - The Future Outlook

Markets

Notwithstanding the recent weakness in North American auto and truck markets, current opinion indicates continued prosperity for the auto industry. All three major manufacturers anticipate a full recovery in vehicle sales and production by late 1976 and continuing growth to 1980. It is unlikely that past periods of rapid sustained expansion are to be repeated. Higher fuel costs, greater emphasis of mass transit commuting, and a leveling off in per capita car ownership will all contribute to holding the expansion of unit output into a range of 5.5 per cent to 6.5 per cent over the coming decade. The value of goods shipped will increase at approximately the same rate as extensive redesigning will be necessary to meet regulatory and marketing needs.

Conservation

Within the industry appreciable efforts toward reduced energy consumption are already under way. These are directed largely toward more efficient space heating methods in plants and office buildings. Plant operations, with special emphasis on the upgrading of paint apparatus, are also being examined for possible energy savings. Overall savings of 15 per cent of present per unit energy requirements have been established by the Motor Vehicle Manufacturers Association as a target level achievable before 1985. Those savings will largely come from the areas mentioned above and the trend to lighter and smaller vehicle design.

The possibilities of dramatic reduction in Ontario's energy consumption arising from this sector are small.

Total consumption represents 1.5 per cent of total provincial industrial consumption. In terms of the output and employment supported by the industry, energy use is very efficient.

Technology

Developments in paint chemistry, application and drying are at present the most relevant to energy consumption in this sector. Water base and powder paints as well as improvements in drying methods could result in savings in natural gas usage of 10 to 15 per cent by 1985. The introduction of fast air drying paints currently being developed could at some future date eliminate the use of fuels for this purpose. In both cases no increase in electricity consumption is expected. Electrostatic paint application is an additional technology in this area which would reduce natural gas consumption but at the expense of some increase in electricity consumption. Unfortunately, no additional information was available on this procedure.

Paint drying processes will change for two reasons. Firstly, new painting methods, e.g. fast air drying paints could eliminate the need of drying and baking. The industry feels these developments will occur in the long run. Secondly, the use of electric ovens instead of natural gas ovens in the paint shop would change the consumption patterns of the industry. Increased use of plastic components for automobiles requires the industry to increase the use of low temperature drying ovens (especially electric) and decrease the use of the high temperature natural gas ovens. In the future, the new paint technologies would increase this substitution. The

requirement for clean heat in the drying/baking process allows a substitution only between electricity and natural gas.

Since research and development in product design and production methods is very rapid in vehicle manufacture, other techniques for energy savings are liable to occur but are very difficult to anticipate in advance. However, as suggested above, developments within this sector are unlikely to have sudden or major influence on Ontario's energy budget.

3.3.6 - Industry Model

Energy consumption in the automobile manufacturing industry has been segregated into three processes:

- Assembly and space heating,
- Painting and paint drying, high temperature,
- Painting and paint drying, low temperature.

There appears to be no significant difference in energy usage as the vehicle size and weight changes. However, the recent emphasis on energy may, in all phases of the auto industry, make it possible to isolate this change, in terms of energy, in the future.

The total number of automobiles produced in Ontario was estimated from data provided by, and discussions with, the Canadian Motor Vehicle Manufacturers Association. Data by year by vehicle model was available for all Canada. Ontario output was estimated by the model types known to be produced in the province.

The original regression equation of auto output gave an excellent fit using the relationship of per capita disposable income in the two major market areas. However, long-term projection with this formula generated an obviously unrealistic level of output for Ontario of 6.5 million vehicles as compared to a North American production of 15 million. Long-term growth, therefore, has been tied to an Ontario market share that remains constant at 11.4 per cent of total.

(3.1) ... OAUTO = 0.114 (AUTOP)

The model accommodates both high temperature curing (using natural gas) and low temperature curing (using electricity). Advances in painting technology may require three or more processes instead of only the two presented here. In general, the automobile bodies undergo the high temperature curing while the painted components, usually plastics, require lower temperatures. Currently approximately 140[1] pounds of components per vehicle require the low temperature. This figure is bound to increase (in fact, 1977 figure is expected to be in the order of 200 pounds)[1] as automobile manufacturers strive to reduce the total weight of the vehicles.

An increase in the number of components subjected to low temperature will generally indicate a decrease in the number in the high temperature ovens. Energy consumption in the high temperature ovens is based on the number of vehicles produced in the industry times a factor to reflect the substitution. The factor is the ratio of the "amount" of the vehicle exposed to the ovens in a given year to the "amount" currently using the high temperature

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[1] Business Week, August 2, 1976.

ovens. The current value is therefore 1.0. It is estimated that approximately 2,500 pounds of steel is used in an average North American automobile.[1] If we use this number as a proxy for the amount of high temperature paint drying and if steel input is forecast to decrease to 2,000 pounds by 1985, the factor for 1985 would be 0.8. Thus the measure for high temperature paint drying is:

(3.2) ... q_1 = OAUTO x factor.

The measure of input to low temperature paint drying is based on the number of pounds of components per vehicle requiring the process, and expressed in tons:

(3.3) ... q_2 = (OAUTO x pounds)/2,000

The per unit energy requirements are provided in Table 3.3b.

Industries consuming large amounts of electricity and heat in the form of steam such as the automotive industry might benefit from in-house generation. The particulars of such an installation are beyond the scope of this study as they would be specific to a given plant and plant location.

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[1] Ibid.

TABLE 3.3a

VARIABLES IN OUTPUT FORECASTING EQUATION

Year (t)	Dependent Variable (OAUTO)[1]	Independent Variable (AUTOP)[2]
1964	539,572	8,293,600
1965	687,672	9,996,586
1966	690,354	9,292,381
1967	709,733	8,150,848
1968	886,179	9,714,007
1969	1,019,600	9,260,490
1970	919,469	7,488,310
1971	1,074,370	9,679,645
1972	1,137,832	9,982,377
1973	1,224,117	10,903,647

1 Total number of passenger vehicles produced in Ontario. Source: Canadian Motor Vehicle Manufacturers Association.

This figure does not include truck production and is being used as a surrogate for the total output of the industry.

2 Total number of passenger vehicles produced in North America. Source: Canadian Motor Vehicle Manufacturers Association.

TABLE 3.3b

PER UNIT ENERGY REQUIREMENTS
AUTOMOBILE MANUFACTURERS

(Btu x 10^6 /unit)

Production Process (variable)	Energy Form			
	Fuel Oil	Natural Gas	Coal	Electricity
Assembly and space heating and utilities (OAUTO)[1]	2.64	2.24	1.67	1.76
Paint drying and baking:				
High temperature (q_1)[2]	-	1.3	-	-
Low temperature (q_2)[3]	-	-	-	3.6

Source: Acres' Survey and estimates.

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1 Units are number of passenger vehicles.

2 Units are number of passenger vehicles times a factor.

3 Units are tons of components.

3.4 - Cement

3.4.1 - Industry Overview - Energy Use

In 1973 Ontario cement manufacturers consumed over 22.3×10^{12} Btu of energy. This represents some 2.7 per cent of total industrial energy consumption. The industry is one of the most energy-intensive in the province having the highest level of energy consumption per employee. This simply reflects the capital-intensive low-labour force structure of cement manufacturing and is not a reflection of energy efficiency. Cement also shows the second highest consumption level per dollar of value added and dollar of shipments. Energy sources for the industry in 1973 were: coal (18%), fuel oil (32%), natural gas (42%) and electricity (8%).

Requirements for individual forms of fossil fuel cannot be viewed as absolute for a certain degree of interchangeability is possible. The actual split between various fossil fuels used in a given year is a function of relative prices and the ability of the manufacturer as the result of storage and burning equipment, to take advantage of favourable prices. Only for electricity is there no ready substitute.

3.4.2 - Industry Overview - Markets

Ontario's cement plants not only supply Ontario with cement but also serve the Western New York State cement market. The annual production capacity of these plants was 6.6 million tons in 1976.

The total market for Ontario cement is currently in the order of 4.6 million tons annually including about one million tons of exports. The plants are therefore working substantially below capacity and in the short run at least the export markets are quite important to the companies in helping to maintain efficient levels of production.

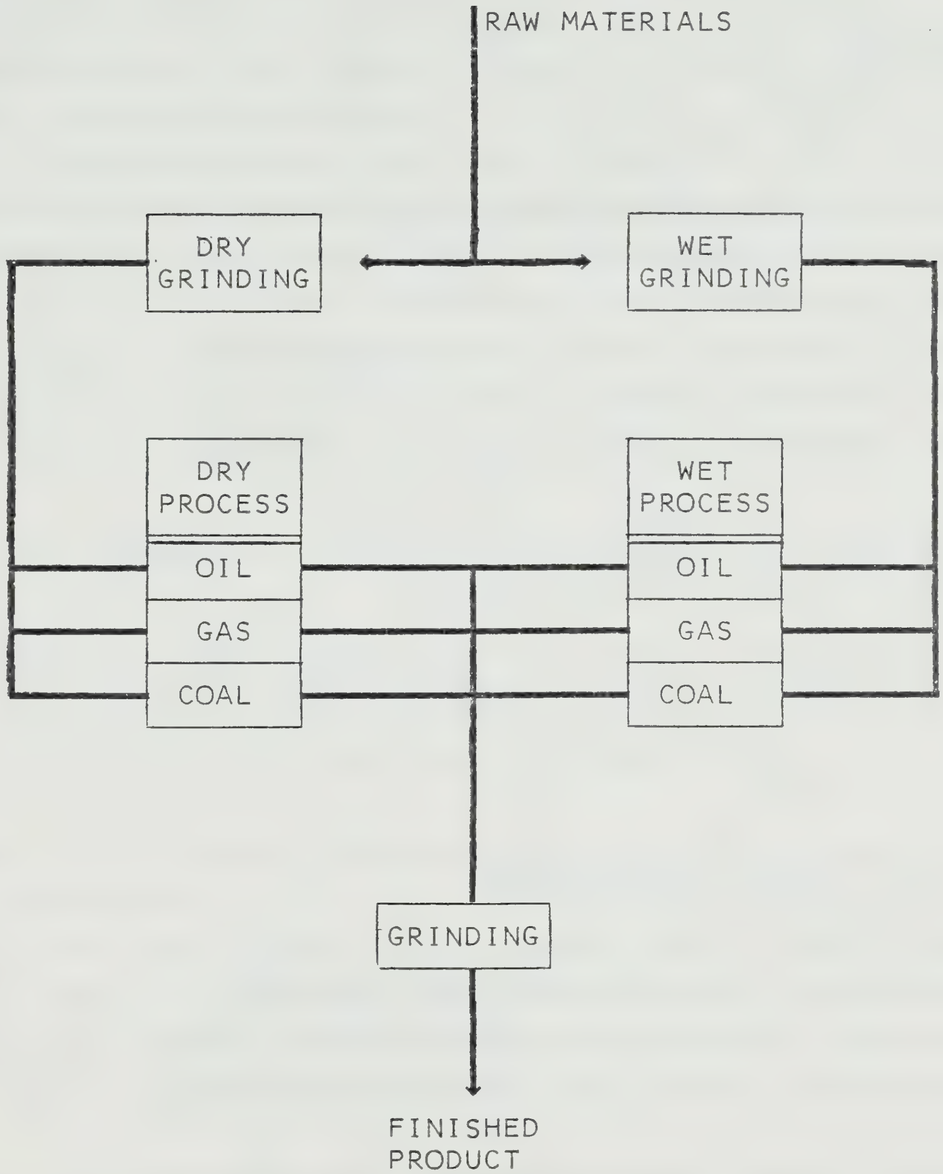
The companies, however, do not gear their Canadian production to the export market and the current situation is considered as a temporary phenomenon brought on by excess capacity in the industry.

3.4.3 - Production Process

The cement manufacturing process consists of reacting various ground natural materials containing lime, silica and alumina at a high temperature to produce a sintered material called "clinker", which is finely ground to form the cement product. The method of blending and grinding the raw materials to be fed to a kiln determines if the facility is a "wet" or a "dry" process.

The wet process grinds and blends the raw materials in a water slurry. While this process is more energy-intensive in later stages of production, it has advantages if the raw materials initially contain large amounts of moisture (in the order of 20 per cent). The alternative, the dry process, entails drying to remove water that may be in the materials as they come from the ground or from rainfall, grinding and blending the raw materials and feeding this dry meal to the kiln. Dry grinding requires slightly more energy than wet, but there are substantial energy savings in the kiln as excess water does not have to be evaporated.

PRODUCTION PROCESS
CEMENT



The most energy intensive process in cement manufacture is the "burning" or "calcining" of the raw materials in a rotary kiln. The kiln is a long, cylindrical, brick-lined furnace, mounted at a slight incline to the horizontal which rotates on its axis at approximately 1 to 2 rpm. The raw meal from the grinding and blending operation is introduced at the top of the kiln. The process heat is produced by firing coal, gas or oil at the lower end of the kiln. This countercurrent flow of raw materials and hot gases raises the temperature of the meal and causes the chemical reactions that form the cement clinker.

The final process involves grinding the clinker and adding gypsum to form portland cement.

3.4.4 - Energy Consumption

Electricity is indispensable with major uses being in the grinding of both raw materials and cement clinker. Fossil fuels are required primarily for kiln firing, which consumes about 96 per cent of a plant's fossil fuel use.

Ontario cement plants use oil, coal, natural gas or a combination of these to fire their kilns. Selection of a given energy form depends primarily on price and availability, with the added consideration that the appropriate fuel storage, handling and burning equipment must obviously be available at the given plant. Those plants that have multiple fuel capability can and do switch from one form of fossil fuel to another on a seasonal basis. Frequent change-overs from one fuel to another are undesirable in

that they necessitate kiln shutdowns causing losses in production and kiln heat. Natural gas is the preferred fuel because of its relative ease of handling when compared with other fuels.

In 1973 the distribution of total energy consumption throughout the cement production processes[1] was as follows:

Raw grinding	4.6%
Kilns	83.0%
Finished grinding	7.3%
All other	5.1%
	100.0%

Total energy consumption per ton of cement in Ontario in that year was 5.32 million Btu, of which 413,000 was electricity and the remainder was fossil fuels.

There are six areas where heat is utilized and lost in the kiln operation:

- theoretical reaction heat
- water evaporation
- exit gas heat
- dust carryout heat
- clinker retained heat
- radiation and convection.

The use of chains, dust collectors and insulation have been installed in some plants to reduce these losses and recycle the energy.

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[1] Portland Cement Association.

3.4.5 - The Future Outlook

Markets

The market for cement has a past record of relatively stable growth of about 3 to 3.5 per cent per year. Growth is closely tied to overall prosperity in the economy and particularly to investment in heavy construction projects Indeed, the industry spokesmen claim a long-term relationship that can be used for forecasting purposes exists between output and population. For the model, output forecasts will be based on Canadian forecasts of construction investment.

In the short run, exports are an important consideration as this market in the U.S. will be used to supplement the Ontario market under conditions of overcapacity in the industry. The following table shows the expected total market through 1981.

ONTARIO CEMENT MARKET

Year	Ontario Demand	Export (Millions of Tons)	Total
1976	3.6	1.0	4.6
1977	3.5	1.0	4.5
1978	3.6	1.0	4.6
1979	3.7	1.0	4.7
1980	3.9	1.0	4.6
1981	4.0	1.1	5.1

Growth of market:

Ontario - use 3 - 3.5 per cent.

Export - after 1980 use 1.1 million tons/year
includes 0.3 million tons of clinker

This overcapacity probably means that no addition to manufacturing capacity can be expected until at least the mid-1980s, unless the present market growth trends change drastically. The substantial excess capacity to Ontario's requirements that will exist for the next decade should tend to promote substantial competition both in the Ontario and export markets.

The total annual capacity of <u>dry</u> kilns in Ontario is 3.8 million tons and <u>wet</u> kilns capacity is 2.7 million tons (1976). The average Canadian kiln capacity is approximately 700 tons per day. While most capacity additions have been dry kilns, several wet kilns have been constructed to suit the moisture characteristics of the raw materials or to match financial constraints.

Wherever possible, plants are built (or rebuilt) using the dry process, the rationale being energy economics. In the longer term, it is anticipated that wet capacity will be maintained at present levels and on balance additions to capacity will be dry process. This assumes some new wet capacity may be added but some current wet process capacity will be rebuilt with dry capacity.

Conservation

Only modest potential exists for the Ontario cement industry to reduce energy use without major capital outlay. The Canadian Portland Cement Association, in its presentation to the Second Industrial Energy Conservation Conference, Ottawa, March 24, 1976, committed itself to a voluntary reduction in average national energy use per unit output of 9 per cent to 12 per cent by 1980, based

on 1974 energy use. Obviously, certain conditions were specified when this industry announced its intentions. Of major significance is the fact that much of the announced planned reduction in average energy use is predicated on the construction of new plant.

For example, since 1973, the following has occurred:

- A major new plant that came on stream in late 1973 experienced its first full year of production in 1974.

- In early 1975, a new dry kiln began to operate in Eastern Ontario.

- An addition to existing facilities in South-western Ontario will reduce unit energy consumption at that plant starting in late 1976.

By late 1976, the industry will have almost attained the reduced level of energy consumption that can be expected to prevail for the next decade. After 1976, additional potential for reducing energy consumption per unit of output is minimal without major capital expenditure.

Recent American data[1] suggests that new wet kilns use 75 per cent of the fossil energy input per unit output of the average wet kiln in use today. New dry kilns (i.e. those with suspension preheaters) use approximately 70 per cent of the fossil energy of the average wet kiln. Canadian

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[1] Gordian Associates, The Potential for Energy Conservation in Nine Selected Industries.

Portland Cement Association, Energy Conservation in the Cement Industry.

industry sources[1] state that converting from an inefficient wet to dry process with the introduction of a suspension preheater could reduce kiln fuel requirements 25 to 30 per cent.

As the industry expects substantial over-capacity for the next decade, neither this conversion nor new capacity is expected within that time period.

In this capital and energy-intensive industry, producing large quantities of low-cost basic construction material, it is impossible to justify major plant conversions solely for the purpose of saving energy and energy costs. Such savings, even taking into account possible rises in the costs of fuel, cannot justify the capital outlays in that they contribute little to overall productivity in the manufacturing process except in energy usage. In other words, a very high fuel price or a very substantial incentive would be necessary to encourage energy efficiency in established and still useful plants. The cost of converting from wet to dry process is estimated at $50 per producing ton or about $20 million for a 400,000-ton per year plant.

Technology

Energy consumption in this industry is basically a function of moisture content of the raw feed entering the kiln. The primary direction of conservation measures, other than strictly housekeeping, has been to capture and recycle the waste heat to be used to reduce the moisture content. The following Figure illustrates this relationship between moisture content and heat requirement.

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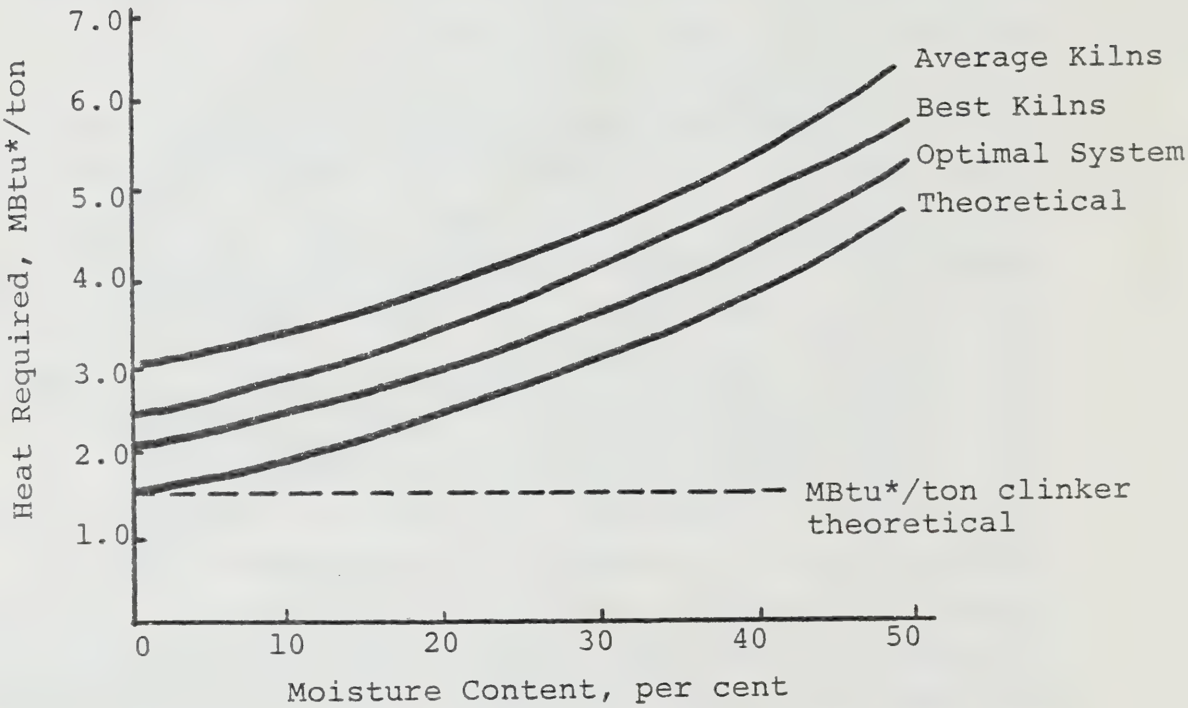
[1] Portland Cement Association.

Effect of moisture on heat requirements



* MBtu - millions of British Thermal Units

Source: American Portland Cement Association

The position of any kiln on the curves presented in the figure will depend upon the design of the kiln, residence time of clinker in the kiln, use of chains to increase heat transfer and reduce dust loss, temperature of output clinker and of output gases, use of preheaters for air and raw feed and dust recovery equipment.

Some of the difficulties associated with the installation of the new energy-efficient kilns that are now available in Ontario within the next 10 years will be the lack of a market for new capacity, high cost of capital equipment and of money and finally, the existence of considerable newly-installed capacity which will not be depreciated for many years. Therefore, in the longer term future (after 1986) it can be assumed that most capacity will be converted to the suspension preheater kilns process. All new dry capacity will be of this type as will replacement to current capacity.

3.4.6 - Industry Model

The basic structure of the cement industry model evolves from the various process-fuel combinations associated with the industry. Nine processes have been isolated.

- Dry process (oil-fired)
- Dry process (gas-fired)
- Dry process (coal-fired)
- Wet process (oil-fired)
- Wet process (gas-fired)
- Wet process (coal-fired)
- Dry grinding (including preliminary drying)
- Wet grinding
- Finished grinding

Each of the six heating processes requires the major fuel listed in parentheses for process heat plus electricity for kiln rotation. The grinding operations require only electricity.

The output measure for the industry is the volume of cement produced in a given year. The demand for cement reflects its primary use, construction, as measured by the value in constant dollars of construction investment in Canada (Table 3.4a).

(4.1) ... $Q_t = 924{,}998 + 246.5\ (CCON)$

where, Q_t is the volume of cement in tons,
CCON is the value of construction investment in Canada in millions of 1971 dollars.

The production of this total cement demand must be assigned to the two major processes: wet and dry. Neither process requires the exclusive use of one particular fuel. Based upon three fossil fuels (coal, fuel oil and natural gas) and two basic processes (wet and dry), there are six possible methods by which cement is produced. All six are utilized in varying degrees in Ontario. Without the benefit of a detailed survey of all cement plants in the province, it was necessary to estimate production by process based on published capacity process, fuel capability and total energy consumption data. The following table lists this data and the estimates of production proportion by process for 1976. The fuel capability only reflects the ability of the plant to switch from one fuel to another, where there is a choice either fuel could be used exclusively.

The fuel split is based on those proportions which were necessary to balance production and the per unit energy requirement to the total consumption of the industry. This balance was based on 1973 data as that was the most recent year for which all data was available. The table has been updated to reflect the 1976 industry profile. It was also necessary to assume that all plants were operating at the same percentage of capacity.

ONTARIO CEMENT INDUSTRY, 1976

Plant	Capacity	Process	Fuel Capability	Assumed Split
	(000 tons)			(%)
1	595	wet	gas/coal	90/10
2	1,100	dry	gas/oil	60/40
3	875	dry	gas/coal	90/10
4	850	dry	gas/coal	90/10
5	750	wet	oil/coal	90/10
6	1,000	dry	oil	100
7	700	wet	gas/oil	60/40
8	700	wet	coal	100

PRODUCTION PROPORTIONS, 1976

	Dry		Wet		Total	
	(tons)[1]	(%)	(tons)[1]	(%)	(tons)[1]	(%)
Fuel oil	1,440	21.9(p_1)	955	14.5(p_4)	2,395	36.4
Natural gas	2,213	33.7(p_2)	956	14.6(p_5)	3,169	48.3
Coal	172	2.6(p_3)	834	12.7(p_6)	1,006	15.3
Total	3,825	58.2	2,745	41.8	6,570	100.0

[1] Tons of capacity, in thousands.

New plant can be accommodated in the model including the new process classifications (e.g. new wet) in the above table and computing the new production proportions table. There will also be corresponding entries in the per unit energy consumption table (Table 3.4b). For existing plant:

(4.2) ... $q_1 = p_1 \ (Q_t)$
$= $ tons by oil-fired dry process, 1976 value of p_1 is 0.219

(4.3) ... $q_2 = p_2 \ (Q_t)$
$= $ tons by gas-fired dry process, 1976 value of p_2 is 0.337

(4.4) ... $q_3 = p_3 \ (Q_t)$
$= $ tons by coal-fired dry process, 1976 value of p_3 is 0.026

(4.5) ... $q_4 = p_4 \ (Q_t)$
$= $ tons by oil-fired wet process, 1976 value of p_4 is 0.145

(4.6) ... $q_5 = p_5 \ (Q_t)$
$= $ tons by gas-fired wet process, 1976 value of p_5 is 0.146

(4.7) ... $q_6 = p_6 \ (Q_t)$
$= $ tons by coal-fired wet process, 1976 value of p_6 is 0.127

Therefore, total tons requiring dry grinding is:

(4.8) ... $q_7 = q_1 + q_2 + q_3$

and total tons requiring wet grinding is:

(4.9) ... $q_8 = q_4 + q_5 + q_6$

No allowance has been made for the production of clinker for export. This product would require less finished grinding and none of the mixing associated with the production of portland cement. This omission results in an overestimate in total energy consumption of approximately one quarter of one per cent.

Energy use per ton of output of the cement kilns varies dramatically from plant to plant. The following lists the fossil energy consumption for some typical systems:[1]

	10^3 Btu/ton of clinker
Wet - coal-fired (U.S.)	5,500
- old plant average (world)	6,910
- new plant average (world)	4,790
- average (U.S.)	6,491
- with light chains (U.S.)	6,750
- with dense chains (U.S.)	5,600
- best wet system (U.S.)	4,400
Dry - oil-fired (U.S.)	4,032
- new plant average (world)	2,925
- best dry system (U.S.)	3,400
- with chains (U.S.)	4,300
- average (U.S.)	5,449
- suspension preheater type (U.S.)	2,984
- suspension preheater average (U.S.)	4,562

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[1] Gordian Associates, The Potential for Energy Conservation in Nine Selected Industries.

Portland Cement Association, Energy Conservation in the Cement Industry.

There are also variations in energy consumption based on the fuel used. The performance of a large number of plants using coal, oil and gas kilns leads to the following figures:[1]

	10^3 Btu/ton of cement
Oil-firing	6,810
Coal-firing	6,380
Gas-firing	5,890

These figures include many small and old plants as well as wet and dry processes.

For this study we have selected energy consumption figures of 6.0×10^6 and 3.9×10^6 Btu per ton of cement for the wet and dry processes respectively. These figures are lower than the above figures reflecting the more modern Ontario kilns. Lack of data preclude a statement on the conversion efficiency of the three fossil fuels and the three are assumed identical (Table 3.4b).

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[1] Ibid.

TABLE 3.4a

VARIABLES IN OUTPUT FORECASTING EQUATION

Year (t)	Dependent Variable (Q_t)	Independent Variable (CCON)
1964	3,043,771	7,829
1965	3,145,873	8,455
1966	3,242,591	8,942
1967	2,894,483	8,634
1968	3,103,849	9,062
1969	3,112,697	9,502
1970	3,142,511	9,433
1971	3,573,364	10,442
1972	3,270,820	10,936
1973	4,197,754	12,003

where, Q_t is total tons of cement produced in Ontario
Source: Statistics Canada 26-201.

CCON is the total value of construction investment in Canada, in millions of constant 1971 dollars.
Source: Statistics Canada.

TABLE 3.4b

PER UNIT ENERGY REQUIREMENTS
CEMENT MANUFACTURING

(Btu x 10^6/unit)[1]

Production Process (variable)	Energy Form[2]: Fuel Oil	Natural Gas	Coal	Electricity
Finished Grinding (Q_t)	-	-	-	.21
Dry Process:				
Grinding (q_7)	-	-	-	.1
Oil-fired (q_1)	3.9	-	-	.1
Gas-fired (q_2)	-	3.9	-	.1
Coal-fired (q_3)	-	-	3.9	.1
Wet Process:				
Grinding (q_8)	-	-	-	.09
Oil-fired (q_4)	6.0	-	-	.1
Gas-fired (q_5)	-	6.0	-	.1
Coal-fired (q_6)	-	-	6.0	.1

1 Units are tons.

2 Acres estimates based on general conclusions in Gordian Associates study, Portland Cement Association and Statistics Canada.

3.5 - Clay Products

3.5.1 - Industry Overview - Energy Use

This industry is not among the leaders in total energy use in Ontario but it is an energy-intensive sector in terms of energy input per dollar of output. This reflects the low value of the output and the basic nature of the process (baking raw materials with little actual processing). This industry also provides some insights into the considerations that affect fuel selection, fuel use and improvements in fuel efficiency in industry. During 1973, this industry used 5.1×10^{12} Btu, or 0.6 per cent of the use by the total Ontario industrial sector. The distribution by fuel type was, natural gas (80%), coal (9%), fuel oil (5.5%) and electricity (4.5%).

3.5.2 - Industry Overview - Markets

The Ontario brick market is estimated at between 250 and 300 million bricks per year. It fluctuates with construction activity. The great weight of bricks makes it uneconomic to transport them over great distances and therefore the market and production is locally based.

Natural gas is the preferred fuel of this industry, primarily because of product appearance. Gas-cured bricks do not develop discolourations as is the case with oil-cured bricks. However, the use of fuel oil does not compromise product quality, only the colour. Marketing the "new" product is the major deterrent to the change and would be facilitated if the whole industry were to switch to fuel oil.

3.5.3 - Production Process

The most significant output of this industry is the building brick. It will be the focus of this model. The building brick, with which everyone is familiar, is formed of clay or similar substance and baked in a kiln. Though the composition, appearance, weight and texture of a brick comes in an infinite number of varieties, its manufacture essentially consists of mixing the proper ingredients and thereafter curing the bricks in a kiln. The operation can be compared to a commercial bakery.

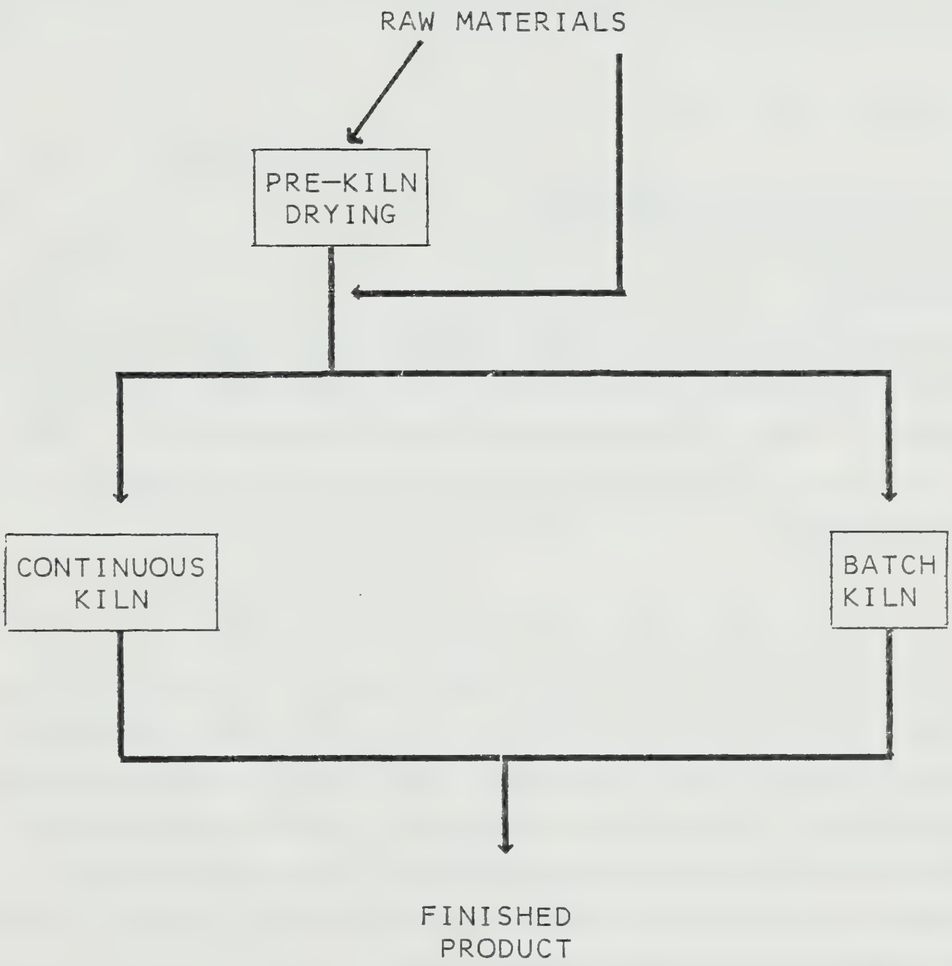
Three basic techniques used to form the bricks and prepare them for the kiln are dry press, stiff mud and soft mud. The latter two methods require that the excess moisture be driven off before the bricks are charged to the kiln. This drying step avoids cracking problems when they enter the kiln. Formerly the "green" bricks were dried in the open air for 5 to 12 days, but more recently drying kilns utilizing waste heat from the burning kilns, have reduced this to two days.

Small, local producers, accounting for no more than 12 per cent of Ontario's brick production capacity, cure or burn their bricks in batch-type ovens. The majority of the bricks, however, are produced on an assembly line basis in continuous ovens or kilns.

3.5.4 - Energy Consumption

Though natural gas is the preferred fuel of this industry, cost of fuel is a most important consideration as this represents more than 25 per cent of the direct cost of manufacturing. Frequent change-overs from gas to oil are

PRODUCTION PROCESS
CLAY



impractical because of substantial product loss with oil, immediately following switch-over. This is because of a severe discolouration problem when using oil at the start-up stage. If oil were used continually, the discolouration is less pronounced and product quality is virtually the same as for gas cured bricks.

3.5.5 - The Future Outlook

Conservation

The installation of new automated kilns could reduce present unit energy consumption by almost 30 per cent compared to the continous kiln now in operation. Here again the size of the capital investment required is the major deterrent.

Without incentives it is reasonable to expect a 10 per cent decrease in unit energy use by 1980, and another possible 10 per cent by 1990. Only the replacement of existing capacity with modern kilns would markedly reduce energy use by this industry. Even though new capacity additions, expected no sooner than 1982, may be very efficient, the existence of old plants will keep average energy use up over the longer term.

Markets

As already noted, because bricks are heavy, markets tend to be localized. This is likely to remain true over the long-run and therefore only Ontario is considered in projections. Real competition for brick, of course, comes from other building materials such as cement, aluminum and steel, and over the longer run it is difficult

to say what major changes will occur in this situation. Basically, our outlook gears brick demand to local economic indicators and to past trends which indicate slow growth, being only 2.77 per cent per annum over the 1964-1973 period.

3.5.6 - Industry Model

This industry is characterized by the production of construction bricks. Two operations are involved, drying (in preparation for the kiln) and kiln firing (either continuous kilns or batch kilns). Three processes are identified:

- Drying,
- Continuous kiln firing,
- Batch kiln firing.

Data in the clay products industry is concentrated in the production of clay bricks. Brick production data in Ontario is available in aggregate only, i.e. no indication is given of the production process. To this end the Canadian production proportions by process were applied to the provincial totals to obtain data by process. Over the past ten years (1964-1973) the average proportion of the total production of bricks in the country accounted for by the dry press process is approximately 14 per cent. Eighty-six per cent of the total was produced by the stiff mud process. The soft mud process has been ignored because it represents only a small proportion of the total production. Thus, 86 per cent of the total require drying before they are fed to the kiln.

Current estimates of production by batch kilns represents some 12 per cent of the total production. These kilns are largely used in small operations where large volumes are not required. Continuous kilns produce the largest volume of bricks in the province, some 88 per cent. One cannot expect the batch kiln to be phased out, despite its higher energy consumption because it is more energy-efficient for small special product runs.

These data allow us to estimate the throughput of the three production processes in the model.

Total brick production has been related to provincial value of construction investment, the forecast equation is:

(5.1) ... $Q_t = 165{,}485 + 50.7\ (OCON)$

where, Q_t is total provincial production of bricks in thousands,

OCON is value of construction investment in Ontario in millions of constant 1971 dollars.

Assumed production by stiff mud forming process is:

(5.2) ... $q_1 = p_1\ (Q_t)$

= thousands of bricks, current value of p_1 is 0.86

Assumed production by continuous kilns is:

(5.3) ... $q_2 = p_2\ (Q_t)$

= thousands of bricks, current value of p_2 is 0.88

Assumed production by batch-type kilns is:

(5.4) ... $q_3 = (1.0 - p_2)\ Q_t$

= thousands of bricks

If new and more efficient kilns are to be included in the model, a fourth measure, q_4, would be generated to account for the production of this kiln type. The parameters which currently generate q_2 and q_3 would also be adjusted. An additional row would be required in the per unit energy matrix (Table 3.5b).

The per unit energy consumption figures were derived from the literature and confirmed in the industry survey. Based on the total energy consumption data and the fact that continuous kilns are twice as efficient as batch kilns, we were able to derive the fact that continuous kilns average 15.0 x 10^6 Btu per 1,000 bricks.[1] There was no information available on production split by fuel type, although it is evident that the majority of the kilns use natural gas. However, the data makes an allowance for fuel oil and coal based on its apparent consumption.

A small amount of electricity for motive power in the drying kilns and continuous kilns is included in the model.

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[1] The Conference Board, Energy Consumption in Manufacturing.

TABLE 3.5a

VARIABLES IN OUTPUT FORECASTING EQUATION

Year (t)	Dependent Variable (Q_t)	Independent Variable (OCON)
1964	270,393	2,396
1965	276,571	2,416
1966	317,111	2,801
1967	318,529	2,804
1968	317,329	3,064
1969	359,127	3,221
1970	301,474	3,252
1971	278,264	3,609
1972	331,260	3,625
1973	353,108	3,712

where, Q_t is total production of bricks (in thousands) for Ontario by stiff mud and dry press process,

OCON is total value of construction investment in Ontario in thousands of constant 1971 dollars.

TABLE 3.5a (cont'd)

ESTIMATES OF OUTPUT - CLAY PRODUCTS

Year	Total Output	Stiff Mud[1]	Dry Press[1]	Batch Kilns[2]	Continuous Kilns[3]
		(thousands of bricks)			
(t)	(Q_t)	(q_1)	-	(q_3)	(q_2)
1964	270,393	231,542	38,851	32,447	237,946
1965	276,571	228,067	48,504	33,189	243,382
1966	317,111	274,830	42,281	38,053	279,058
1967	318,529	282,534	35,993	38,223	280,306
1968	317,329	270,680	46,647	38,079	279,250
1969	359,127	333,988	25,139	43,095	316,032
1970	301,474	272,232	29,242	36,177	265,297
1971	278,264	229,846	48,418	33,392	244,872
1972	331,260	270,639	60,621	39,751	291,509
1973	353,108	270,480	82,628	42,373	310,735

[1] Based on Canadian averages by forming process.

[2] Based on 12 per cent of total production.

[3] Based on 88 per cent of total production.

TABLE 3.5b

PER UNIT ENERGY REQUIREMENTS
CLAY PRODUCTS

(Btu x 10^6/unit)[1]

Production Process (variable)	Energy Form[2] Fuel Oil	Natural Gas	Coal	Electricity
Drying Kiln (q_1)	-	-	-	.45
Continuous Kiln (q_2)	.9	12.8	1.4	.45
Batch-type Kiln (q_3)	1.8	25.5	2.9	-

1 Unit is thousand bricks.

2 Acres' estimates based on relative kiln efficiencies and Statistics Canada consumption data.

3.6 - Food and Beverages

3.6.1 - Industry Overview - Energy Use

The food and beverage industry, ranking second in employment and dollar value of shipments, is a composite sector of heterogeneous enterprises. Total energy consumption in 1973 was 38.1×10^{12} Btu, fuel oil (27.3%), natural gas (51.4%) and electricity (11.6%) were the principal fuels. This total represents 4.6 per cent of total industrial energy consumption in Ontario.

However, notwithstanding the considerable totals for fuels purchased, the food and beverage industry is not an energy-intensive sector. It ranks 16th in Btu per employee, 18th in Btu consumed per dollar of shipments, and 17th in Btu per dollar of value added. Its significance for energy consumption in Ontario lies in its absolute size of operation and output which results in a large demand for energy even though per unit energy requirements are quite low.

3.6.2 - Industry Overview - Markets

Until recently food processing was characterized by numerous small operations geared to serving local markets. Possible exceptions were the breweries and distilleries which have traditionally been quite large, covering extensive market areas. More recently, with the growing concentration of markets in large cities and improved methods of preservation and packaging, the scale of production has increased and the number of operators has diminished. As a result, individual enterprises have been able to expand at a rate considerably above the overall growth of output of 2.5 per cent per annum from

1964 to 1973 by absorbing competitors market shares and by diversifying product lines.

3.6.3 - Production Process

The preparation of foods and beverages falls into three major stages: materials preparation; cooking and processing; final dressing, packaging and distribution. Of these, the first and last stages consist largely of handling, mixing, storage and other mechanical operations. This requires the utilization of electrical power supplemented with natural gas and L.P.G. for drying, liquifying or singeing materials, prior to cooking and processing.

Cooking and processing consists basically of heating, mixing and refrigeration of foods. In this operation the largest fraction of fuel oil, natural gas and coal are consumed. The fuels are required to fire boilers in order to raise steam which is then used to cook the various preparations. In those cases where fuels are used directly, as in bakery ovens or breweries and distilleries, natural gas rather than fuel oil is used. Space heating requirements are also supplied by use of steam generated in boilers as outlined above, while refrigeration units and lighting are powered by electricity.

Gasoline, supplying 9.0 per cent of total energy used in the sector, is used extensively for the collection and distribution of raw materials and finished goods. Since this is not a part of the production process and more properly a part of energy consumption for transportation, the use of gasoline is excluded from the model as presented.

3.6.4 - Energy Consumption

Energy utilization for a typical slaughtering operation is presented below. Similar operations account for approximately 13 per cent of all fuel purchased in this sector. Dairy operations have a similar pattern of fuel utilization, with steam being used for pasteurization and sterilization as well as space heating. However, beverages and bakeries require greater use of fuels directly, while using less for steam generation. Lighting, refrigeration and space heating retain approximately the same relationship to total consumption in all groups.

Energy utilization in slaughtering and meat processing on a Btu basis, is outlined below:

Lighting	1.2%	Boiler Waste	20%
Refrigeration	10.8%	Auxillary Power	15%
Direct Fuel Use	4.4%	Motive Power	4%
Steam Raising	83.6%	Space Heating	10%
	100%	Slaughtering	15%
		Cooking	15%
		Edible Oils	15%
		Rendering	8%
			100%

Source: Canada Packers Ltd.
Toronto

Overall, the food and beverage industry is characterized by a high degree of substitutability among fuels. Fuel oil and natural gas are completely interchangeable on very short notice for the purposes of boiler operation.

L.P.G., when available, at comparable prices, is also easily substituted for natural gas used in ovens and distillery operations. Only in the case of electrical power are food processes committed to a single energy source. The sector would therefore be largely unaffected by scarcities of particular fuels, being capable of circumventing supply problems through substitution.

While consumption of gasoline, coal and fuel oil have tended to decline since 1964, the use of electricity, L.P.G. and natural gas has increased. By 1985, it is anticipated that electrical power will have become far more important to overall fuel usage, accounting for 15 to 20 per cent of total fuel requirements at that time. This will be the result of both the wider application of electricity to operations either not yet mechanized or now using other fuels and an increase in the use of refrigeration at lower temperatures. Natural gas will also displace fuel oil and coal to some extent, supplying 60 to 65 per cent of total energy usage by 1985. This eventuality, however, assumes continuing availability and pricing that equates cost for quantities of fuel oil and gas supplying equivalent energy values. The switch to natural gas will be largely motivated by increasing stringency of environmental regulations.

3.6.5 - The Future Outlook

Markets

The market growth in this sector is expected to be steady and tied to overall growth of population and per capita income within Ontario. In general, national and international markets are considered to be outside the range of Ontario's food and beverage manufacturers making output and fuel consumption dependant on changes in provincial markets. It is anticipated that real dollar value of output will expand at 2.5 to 3.0 per cent per annum, slightly higher than at present due to the continued shift towards pre-cooked and processed foods arising largely from increasing affluence, changing age structure and marital status of Ontario's residents.

Conservation

The low Btu requirements per unit of output and small percentage of total value of goods shipped represented by fuel and electrical costs has resulted in energy conservation being given a low priority in the food and beverage sector. Major producers anticipate a reduction of approximately 10 per cent on per unit energy requirements by 1985. This saving would arise primarily from better plant operation and housekeeping. There is little incentive to undertake investment directed toward reducing fuel consumption since improvements in other areas such as labour productivity and efficient use of raw materials provide greater opportunities for cost reduction and improved profitability. The proportion of energy costs to value of shipments is outlined in the accompanying table.

COST STRUCTURE FOR MAJOR GROUPS IN THE FOOD AND BEVERAGE INDUSTRY, 1973

	Total Fuel Cost($'000)	% of Sector Total	Shipments ($'000)	% of Sector Total	Fuel Costs as % of Shipments
Meat processors	6,524	13.0	1,155,682	23.4	0.5
Beverages (wineries, distilleries, breweries, soft drinks	8,693	17.4	708,245	14.4	1.2
Dairy products	8,357	16.6	603,235	12.2	1.3
Bakeries (bakeries, biscuit manufacturers, feeds, confectionery manufacturers	10,120	20.2	877,808	17.8	1.1
Total		67.2		67.8	

Source: Statistics Canada, 32-202 to 32-224, Ottawa, 1973.

The trend toward large plant sizes may provide some opportunity for energy conservation, though centralizing production will also tend to increase transportation of raw materials and finished goods, reducing the net energy savings achieved. Further, increased mechanization and wider usage of refrigeration in new plants will also tend to hold energy demand at present levels though causing a shift in fuels used.

In conclusion, there is little likelihood of significant changes in energy use in the food and beverage sector. Demand for natural gas and electricity are likely to increase, with the overall Btu consumption continuing to rise with the value of output at 2.5 to 3.0 per cent until 1985.

Technology

Food and beverage manufacture over the last decade has developed a high degree of technical sophistication. Moreover, continued rapid innovation is felt to be central to the sector's goals of product diversification, improved utilization of raw materials and by-products and increased labour productivity. At present, however, the consideration of the efficient use of fuels is not an integral part of development strategies. This arises, as mentioned above, from the cost structure of the industry which limits incentives to reduce energy consumption and to develop energy-efficient techniques. As a result, significant reduction in energy requirements arising from research and development in this sector are not anticipated.

Agencies interested in encouraging a program of energy conservation through technical development should look toward the transfer of efficient technology developed elsewhere to the food and beverage sector. Special emphasis should be given to those innovations such as improved boiler design and building insulation which will provide some savings in fuel use while requiring expenditures very little above normal replacement and maintenance.

3.6.6 - Industry Model

The vast list of products associated with this industry does not lend itself to a process by process model. On the contrary, an extremely general approach is warranted. The output measure of the food and beverage industry used for this model is the value of shipments of goods of own manufacture expressed in millions of constant 1971 dollars. The values were deflated by the price index applicable to the output of the industry converted to a 1971 base. (Statistics Canada 62-002).

The output has been related to population, expressed in thousands. Total output is:

(6.1) ... $Q_t = -747.5 + 0.577\ (POP)$

The per unit energy figures were derived from the gross energy input data over the past 10 years and the value of shipments of goods of own manufacture. There is opportunity for substitution among fuels in the industry as much of the energy is used to generate steam. However, there was insufficient data to allow the model to portray this substitution.

TABLE 3.6a

VARIABLES IN OUTPUT FORECASTING EQUATION

Year (t)	Dependent Variable (Q_t)	Independent Variable (POP)
1964	3,042	6,631.0
1965	3,201	6,788.0
1966	3,294	6,960.9
1967	3,420	7,127.0
1968	3,430	7,262.0
1969	3,480	7,385.0
1970	3,564	7,551.0
1971	3,694	7,703.1
1972	3,839	7,833.9
1973	3,819	7,938.9

where, Q_t is the output measure of the foods and beverage industry, it is expressed in millions of 1971 dollars,

POP is the population of Ontario, in thousands.

TABLE 3.6b

PER UNIT ENERGY REQUIREMENTS
FOOD AND BEVERAGES

(Btu x 10^6/unit)[1]

Production Process (variable)	Energy Form[2] Fuel Oil	Natural Gas	Coal	Electricity
Total shipments (Q_t)	2,676	5,123	24	1,188

[1] Units are millions of constant 1971 dollars.

[2] Acres' estimates based on total energy consumption and constant dollar value of goods of own manufacture.

3.7 - Glass

3.7.1 - Industry Overview - Energy Use

In 1973, Ontario glass manufacturers used 12.2 x 10^{12} Btu of energy. That consumption represents 1.5 per cent of total Ontario industrial energy consumption. High operating temperatures and substantial automation dictate that this industry operate at a relatively high level of energy consumption per employee and high levels per dollar of value added and shipments. Quality control and maintenance considerations have made this industry heavily dependent on natural gas. Of the total fuel consumption, natural gas accounted for 90 per cent, electricity 9 per cent.

3.7.2 - Industry Overview - Markets

Growth of the flat glass industry is closely related to new construction and automobile output. The container portion of the industry is affected by the demand for processed foods (cooked, pickled) in bottles such as baby foods, jams, pickles and beverages such as soft drinks, beer, wine and liquor. Public attitudes to the recycling of glass, both as refillable bottles or as returned broken glass, will affect overall demand for glass containers. Outright legislative action such as that drafted in Ontario to ban or reduce the use of throw-away bottles and cans will also affect demand.

The regional coverage for glass manufacturers is essentially restricted to the Ontario area. Glass, in flat forms, is difficult to ship without damage and containers are not only prone to breakage, they are also bulky and expensive to ship; hence the predominantly local market for glass products.

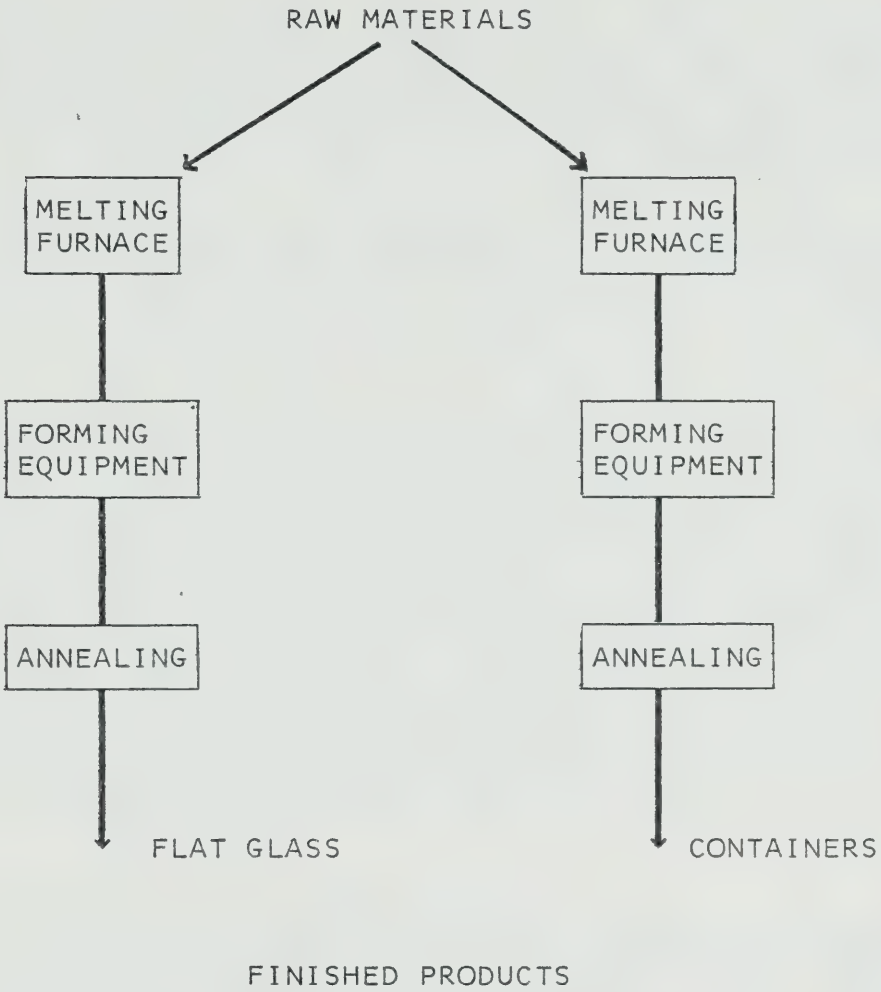
3.7.3 - Production Process

The first stage in any form of glass manufacture is the melting of sand, the chief raw material, and such items as sodium carbonate, limestone and other ingredients, depending on the characteristics of glass required. In the early days of glassmaking, clay pots, heated in ovens stoked with wood or coal, were used for melting. Similar pots made of fire clay and holding between one-half and one and one-half tons of glass are still occasionally employed. However, such batch-type operations now account for no more than 1 to 2 per cent of total glass production.

For the mass production of such items as sheet glass and containers, the modern practice is to use tank furnaces holding, for sheet glass up to 2,000 tons and for containers up to 450 tons of glass at a time. In tank furnaces the raw materials are fed continuously into an opening (called the doghouse) in one end of the tank, while the molten glass is drawn off at the other end. A typical charge for a modern glass furnace making a soda-lime glass consists of up to one-half broken glass fragments, called cullet, with the remainder being a mixture of raw materials of varying composition.

The molten glass is then formed into the desired product. After forming the glass is subjected to an annealing treatment to relieve strains which are set up within the glass as it cools. Annealing, in general, consists of reheating to a temperature high enough so that the strains are eased by flow within the glass, and then cooling slowly, so that very little new strain is set up. The annealing oven is called a lehr.

PRODUCTION PROCESS
GLASS



3.7.4 - Energy Consumption

Energy use within a glass plant at the present time averages about 13.5 x 10^6 Btu per ton of packed glass.[1] Approximately 55 per cent of this is consumed in the melting furnace.

Energy consumption in a modern continuous melting gas furnace is in the order of 7 to 9 x 10^6 Btu per packed ton.[1]

While natural gas is the preferred fuel in the industry, its dominance does not preclude the use of other energy sources. Fuel oil can be used; in fact some furnaces are equipped with natural gas and fuel oil burners. However, the oil-fired furnace must be relined at twice the frequency of a gas furnace. Relining a furnace entails an expenditure of approximately $1 million. In addition, frequent furnace relining is wasteful of the energy used to produce the fire brick used in the furnace.

The disadvantage of oil-firing does not end with reduced furnace life. Present furnaces are designed to operate at maximum output only with gas. Operation with oil as standby fuel would reduce output by approximately 20 per cent. In the long term, furnaces would have to be redesigned for oil-firing. Environmental problems with oil could further reduce output. Since the fuel requirement of a glass furnace per ton of output increases noticeably at lower capacity operation, the fossil fuel consumption

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[1] Acres' survey.

A ton of packed glass implies that the product is ready for shipment, thus energy consumed in the production of glass that has been broken in the production process is included.

per ton of output would rise significantly with the use of oil.

Furthermore, glass quality requirements have improved so much since the general conversion to natural gas some 15 to 20 years ago, that L.N.G., L.P.G. or electricity are now the only acceptable alternatives for natural gas.

Electric furnaces offer an alternative to natural gas furnaces but apparently only if gas were no longer in supply. There are several drawbacks to electric furnaces. Presently there are no electric furnaces on the market that can match the size and output of a natural gas melting furnace, a 260-ton furnace is the largest. Electric furnaces are more efficient as they require only 900 kwh per ton of packed glass (3.1×10^6 Btu) but they command a significant 30 per cent premium in price and their life expectancy between major overhauls is less than one-third that of a gas furnace.

The conclusion to be drawn from the above is that the glass industry can be viewed as virtually gas-dependent. While there are substitute fuels, they are inferior and can only be used with major productivity, environmental and quality sacrifices.

3.7.5 - <u>The Future Outlook</u>

<u>Markets</u>

The glass industry in the past, particularly the container part of the industry, has not been one of dynamic growth. Flat glass has probably fared better as a result of the construction boom of the past decade and the greater use

of glass in both commercial and residential buildings. The market for flat glass will be tied to construction activity in Ontario with some pressure on glass usage as insulation and heat transfer standards in all types of buildings improve. Pressure will not likely appear on flat glass usage because of its energy intensity in production since most of its substitutes such as brick, cement and steel are also energy-intensive. The second market area for flat glass products is in the automobile industry.

Demand for containers has been growing slowly in the past at 2 to 3 per cent per year. This market is highly vulnerable to environmental regulations concerning throw-away bottles and, to some degree, to public attitudes favourable to conserving and recycling glass containers. Demand is also highly price-sensitive at the consumer level. The raising of deposits on beer bottles in Ontario from 2¢ to 5¢ per bottle reduced demand for new bottles by 50 per cent. Similarly, in Alberta large volumes of all types of beverage bottles and cans are being returned as a result of substantial deposits (5¢ on bottles, 2¢ on cans) being paid on what are now non-returnable bottles. Because of these pressures, market growth over the long-run is expected to be quite low and likely related closely to overall population growth.

Conservation

There is no doubt that energy use per ton of product can be reduced in this industry. The melting furnace presents the largest potential for decreasing unit energy consumption. The problem that this industry faces is that the capital cost of attaining a substantially lower

level of energy ugilization is so high that it is not feasible under present circumstances.

It is estimated that the most energy-efficient melting furnace with heat recovery systems can melt glass using approximately 5 to 6 x 10^6 Btu per packed ton. The high temperatures in glass making processes, together with the continuity of the melting process, create opportunities for recovering waste heat. Given specific incentives this industry could generate part, and in specific instances, all of its electrical requirements.

At the second Industrial Energy Conservation Conference it was indicated that the industry would attempt to reduce unit energy consumption by 9 per cent by the year 1980, based on 1972 use. A reasonable estimate for the following ten years is another 10 per cent reduction in unit energy consumption. These are mainly housekeeping and operational savings.

Recycling of glass presents an opportunity for reducing energy use in the melting stage. If the charge to the melting furnace consists of 50 per cent recycled glass, the melting energy requirements are 10 per cent lower than with new raw materials. These energy savings, however, are counterbalanced by glass sorting and collection costs and the danger that a whole tank of glass can be ruined by the inadvertent addition of contaminants.

Technology

No major breakthroughs in technology are expected in this industry. Although no specific data are available, it is suspected that the only technological change in the industry will be in the form of electric booster heaters in the gas furnaces and the recovery of hot exit gases to preheat either the glass feed or the incoming combustion air.

3.7.6 - Industry Model

Two production streams have been postulated for purposes of the model, one for flat glass, the second for glass containers. Each stream consists of three processes:

- Melting of raw materials,
- Forming,
- Annealing.

The most readily available data in the glass industry was the total production of glass (including sheet, pressed, and blown) in dollars for Canada and the provinces. Only very general estimates were found for production of flat glass versus glass containers and that was at the national level. These estimates indicate that approximately 45 per cent of the total value of production is flat glass.

The model originally designed for this industry anticipated an accurate measurement of the two production lines in tons. This has been modified to accommodate the available data. The value of shipments in the industry deflated by the price index applicable to the industry

has been used as a proxy for the output tonnage. Forty-five per cent of this figure is assumed to be associated with the production of flat glass. Demand for new glass containers is therefore:

(7.1) ... $Qc = -241{,}142 + 45.76\ (POP)$

where, Qc is expressed in thousands of constant 1971 dollars,

POP is provincial population in thousands.

Demand for flat glass:

(7.2) ... $Qf = 8{,}377 + 0.846\ (OCON) + 0.074\ (OAUTO)$

where, Qf is expressed in thousands of constant 1971 dollars,

OCON is value of Ontario construction investment in millions of 1971 constant dollars

OAUTO is number of vehicles produced in Ontario.

The total production of glass containers is affected primarily by the refillable bottle. Obviously the greater the proportion of the demand for bottles that is satisfied by refillables, the lower the demand at the bottle manufacturing plant. Three parameters have been included in the model to simulate changes in this demand.

The demand expressed in equation 7.1 is the total provincial demand for new glass containers and implies that a certain number of recycled containers are already in the system. Unfortunately, this number is unknown. The total demand for all glass containers would be represented by a figure larger than that generated by this equation, the difference being the recycled containers already in the system. As the proportion of total demand for glass containers satisfied by refillables increases, relatively fewer new containers are required. The first

parameter (p_1) is this proportion. As was mentioned above, the current value of the parameter is unknown, thus it is necessary to define p_1 as the incremental value of the proportion. Its current value, therefore, would be zero. Its theoretical maximum value would be less than one as it will always be necessary to produce replacements for broken refillable bottles and expansion of the refillable market (which at this maximum value for p_1 would be the total market). If the value of p_1 were set at one, it would mean that the demand for glass containers was fully satisfied by the containers already in the system and no new containers would be required.

(7.3) ... $q_1 = (1.0 - p_1)\ Qc$

The demand for new glass containers projected by equation 7.3 has three components:

1. Production to service the refillable market, replacing broken containers and market expansion;

2. Production of containers which are not now refillable but could be converted to the refillable market in the future (e.g. liquor bottles);

3. Production of all other containers.

Parameters two and three quantify the proportion of the market for new glass containers represented by the first two components. The third component is the remainder.

(7.4) ... $q_2 = p_2\ q_1$

(7.5) ... $q_3 = p_3\ q_1$

(7.6) ... $q_4 = q_1 - (q_2 + q_3)$

Changes in the values of p_2 and p_3 will obviously change the value of p_1 in subsequent years. This relationship could not be formalized due to lack of data.

Current estimates of the values of p_2 and p_3 are based on American data published by the Conference Board.[1] The product mix for the glass containers industry in 1971 lists end uses as:

Product	% of Total dollar value of shipment
Food containers	35
Medicinal, toiletries, cosmetics	15
Household and industrial	2
Beverages (including beer)	33
Liquor and wine	13
Secondary products	2

These data do no more than to set maximum values for the two parameters at 0.33 for p_2 and 0.13 for p_3. No indication was found for the current stock of refillable bottles.

The energy requirement for the manufacture of the molten glass varies with the amount of cullet introduced to the furnace. This proportion is simulated by assuming the existence of a furnace feed entirely by cullet. Such a furnace does not exist and is included here only to allow the user to postulate various proportions of cullet input. Proportions of cullet are simulated by variations in the parameter p_4. The upper limit for cullet in the

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[1] Energy Consumption in Manufacturing.

container process is 60 per cent.[1] However, it appears that most furnaces are utilizing less than 30 per cent. Smaller proportions are anticipated in the flat glass process as recycled bottles and glass are not acceptable as cullet. Only the broken glass from within the plant is utilized as furnace feed. Thus, no parameter is included for cullet in the flat glass process as the breakage and the energy used to re-melt it is assumed to be part of the overall process.

(7.7) ... $q_5 = p_4 \, q_1$

where, p_4 is the proportion of container glass output satisfied by cullet input.

(7.8) ... $q_6 = (1.0 - p_4) \, q_1$

The per unit energy requirements were obtained for the container industry through the survey. The remaining data was based on the relationships between the flat glass and glass containers industry expressed in the literature and the ratio of the American to Canadian average energy consumption.[2]

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[1] Ash tray manufacturers apparently are capable of using 100 per cent cullet.

[2] The Conference Board, Energy Consumption in Manufacturing.

TABLE 3.7a

VARIABLES IN OUTPUT FORECASTING EQUATION

Year	Dependent Variable	Independent Variables		
(t)	(Q_t)	(POP)	(OAUTO)	(OCON)
1964	113,179	6,631.0	539,572	2,396
1965	134,248	6,788.0	687,672	2,416
1966	137,402	6,960.9	690.345	2,801
1967	144,791	7,127.0	709,733	2,804
1968	174,876	7,262.0	886,179	3,064
1969	184,210	7,385.0	1,019,600	3,221
1970	171,125	7,551.0	919,469	3,252
1971	199,704	7,703.1	1,074,370	3,609
1972	203,760	7,833.9	1,137,832	3,625
1973	240,452	7,938.9	1,224,117	3,712

where, Q_t is total shipments of Ontario glass products in thousands of 1971 dollars, Statistics Canada 44-207,

POP is provincial population, in thousands,

OAUTO is number of passenger vehicles produced in Ontario.

OCON is value of construction investment in Ontario in millions of constant 1971 dollars.

TABLE 3.7b

PER UNIT ENERGY REQUIREMENTS
GLASS

(Btu x 10^6/unit)[3]

Production Process (variable)	Energy Form: Fuel Oil[4]	Natural Gas	Coal	Elec- tricity
Flat glass:				
Raw melt (Qt)	-	37.6[1]	-	.9[1]
Forming (Qf)	-	-	-	2.4[1]
Annealing (Qf)	-	9.4[1]	-	-
Containers:				
Raw melt (q_6)	-	36.8[1]	-	.9[1]
Cullet melt (q_5)	-	31.3[2]	-	.9[1]
Forming (q_1)	-	-	-	3.8[1]
Annealing (q_1)	-	9.2[1]	-	-

[1] Derived from Acres' survey and U.S. data converted to Canadian basis based on average per dollar consumption (The Conference Board).

[2] Based on 15 per cent saving using cullet.

[3] Units are thousands of constant 1971 dollars.

[4] A small quantity of fuel oil is consumed in this sector but has been ignored in the model. This is discussed in the Other Manufacturing Sector.

3.8 - Industrial Chemicals

3.8.1 - Industry Overview - Energy Use

In 1973, the production of industrial chemicals required 79.7×10^{12} Btu of energy. The sector ranked third in Btu per employee and fourth in both Btu per dollar shipped and per dollar of value added. The principal fuels used in the sector were fuel oil (35.5%), natural gas (50.4%) and electricity (13.1%). Small amounts of gasoline, coal and L.P.G. were also consumed over the year. In addition to these fuel requirements, natural gas and fuel oil were required as feedstock. Some 22.5×10^{12} Btu were consumed as feedstock in 1973 (3 per cent fuel oil, 97 per cent natural gas).

3.8.2 - Industry Overview - Markets

Historically the industrial chemicals sector has experienced a greater rate of growth than the Canadian economy as a whole. In Ontario the real dollar value of shipments expanded at 6.3 per cent per annum from 1964 to 1973. However, the greater part of this expansion occurred between 1964 and 1968. From 1969 to 1973, the real value of shipments grew at 5.6 per cent per annum in Ontario. Further, in light of the rapid development of ammonia and ethylene production capacity in Alberta, a return to more rapid expansion of shipments in Ontario is unlikely. Therefore, levels of production in the industrial chemicals sector will become more closely linked with overall economic activity in Canada.

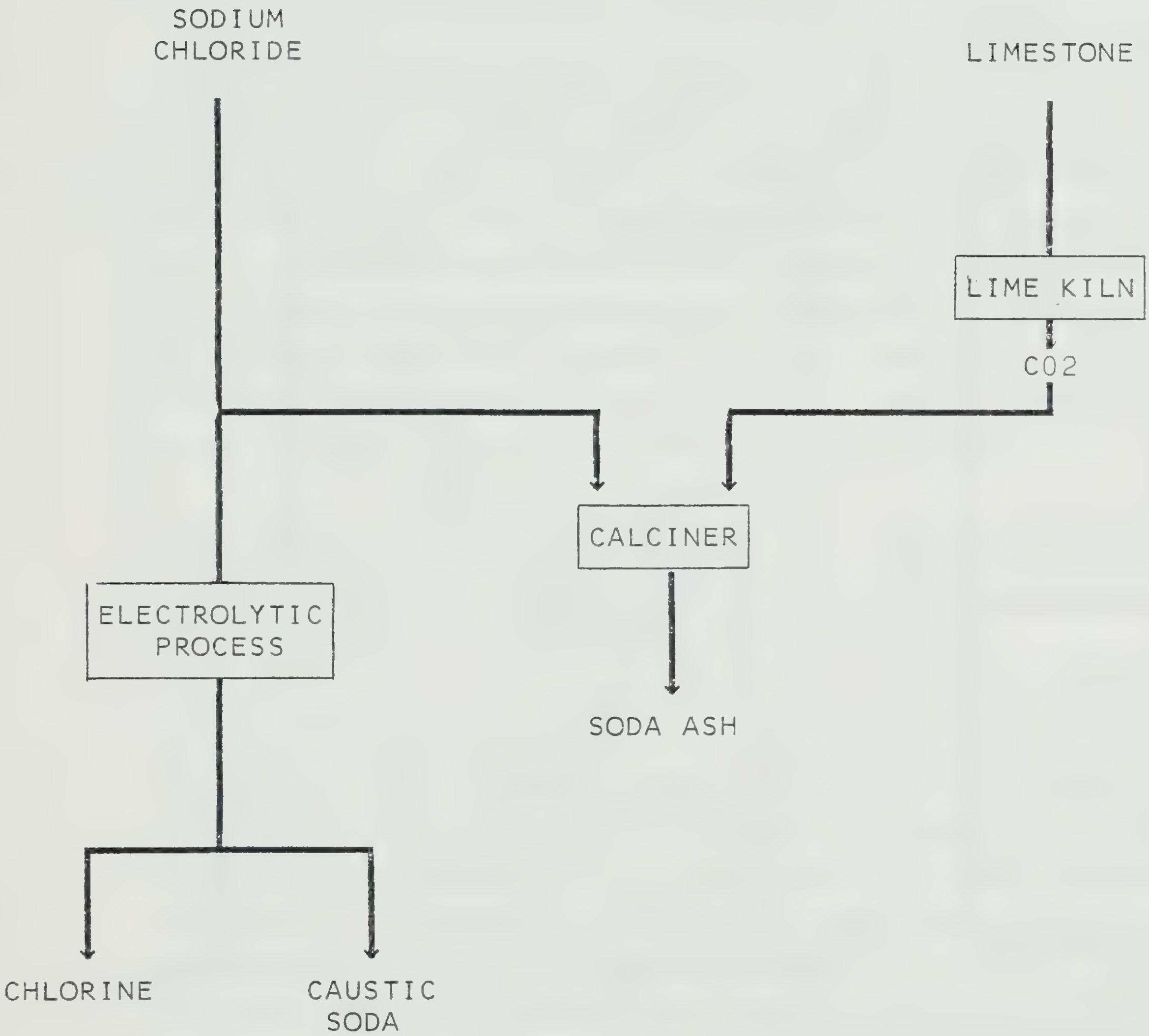
3.8.3 - Production Process

A small sample of the major outputs of the industries have been categorized below:

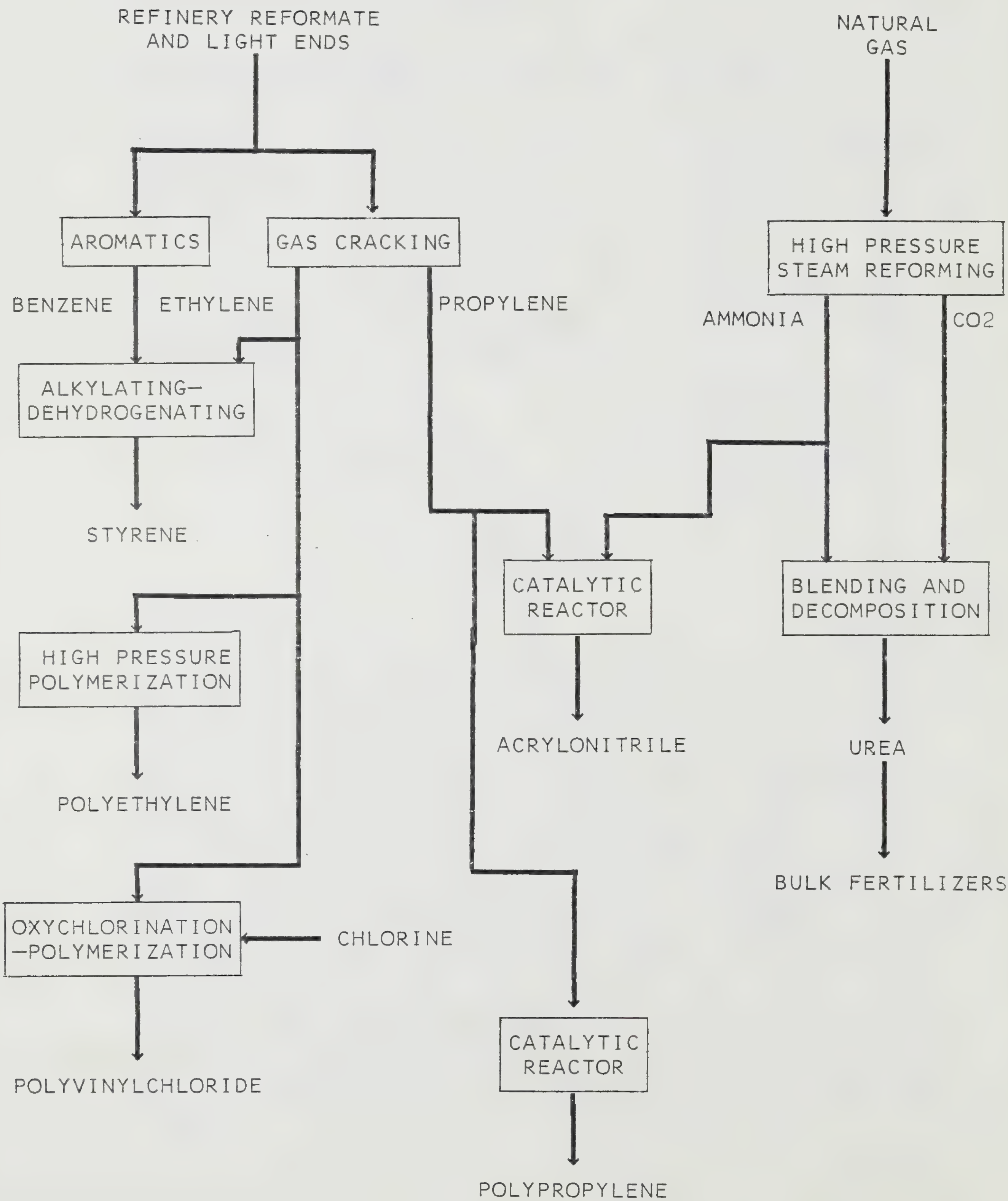
Inorganic: Chlor-Alkali	Inorganic: Other	Organic
Chlorine	Ammonia	Ethylene
Caustic soda	Phosphorous	Propylene
Soda ash	Phosphoric acid	Ethylene dichloride
	Sulfuric acid	Methanol
	Fertilizers	Formaldehyde
	Aluminum sulfate	Ethylene dioxide
	Hydrochloric acid	Acetone
	Potash	Acetaldehyde
	Alumina	Acetic acid
	Sodium	Isopropanol
	Calcium Cloride	Ethanol
	Urea	

Chlorine and caustic soda are produced in cells through the electrolysis of brine. Chlorine in gaseous form is produced at the anode and hydrogen, sodium or potassium compounds at the cathode. A weak caustic solution is drained from the cells after the completion of chlorine extraction. The solution is evaporated and salts removed from it for re-use in the cell brines. The resulting strong caustic is treated chemically to reduce the remaining water content. Contaminants such as sodium chloride and colloidal iron are also removed at this point. The resulting solution may be sold in liquid form or dried, flaked and packaged for shipment. The chlorine gas, meanwhile, is chemically dried, compressed and liquefied for shipment.

PRODUCTION PROCESS
INDUSTRIAL CHEMICALS



PRODUCTION PROCESS
INDUSTRIAL CHEMICALS



The major energy inputs are confined to the operation of the cells, evaporation and liquefying. Steam for heat exchangers and electrical power is produced on site in boilers fired by fuel oil or natural gas. Gas turbine generators have been recently introduced to improve the efficiency of electrical power generation.

Soda ash is produced by the carbonation of an ammonia brine solution;ammonia acting as a catalyst for the re-action. The carbon dioxide required for carbonation is produced by calcinating limestone mixed with coke. The gas is then bubbled through the ammonia brine solution and crude sodium bicarbonate is drawn off. The output is cooled resulting in $NaCO_3$ crystal formation. These are fed into a second calciner where drying is completed. They are then cooled and packaged for shipment.

The chemical reactions involved occur at low temperatures (25°C), the major energy expenditures occurring in the calcinating and dryer stages of manufacture.

Inorganic chemical manufacture requires a wide variety of inputs and processes. In general, however, energy utilization is confined to heating raw materials to the temperatures necessary for reactions to proceed. Calcium chloride, for example, is prepared from quicklime and carbon at 2000°C to 2700°C in electric furnaces. Drying also accounts for significant amounts of energy in the production of some compounds. In all cases the energy sources are natural gas, fuel oil and electricity. In particular cases, small amounts of coal or L.P.G. are used, but are not significant in overall fuel consumption.

The organic industrial chemicals are produced by various chemical conversions of a basic feedstock such as natural gas,naphtha, or light ends produced from refinery cracking operations. Nitration is one of the most important methods of producing intermediates and dyes. Nitro groups rarely appear as final products. Amination by reduction or ammonolysis, oxidation, hydrolysis, alkylation, and sulphonation are all common processes in the manufacture of industrial organics. Halogenation and chlorination in particular are increasingly important in the production of intermediate derivatives.

Although some conversions such as sulphonation are exothermic, large quantities of fuel are required to heat the feedstock stream and reactants, as well as to provide energy to drive turbines, pumps, and compressors.

3.8.4 - Energy Consumption

The industrial chemicals sector is heavily committed to natural gas, low sulphur fuel oil, and electricity. Opportunities exist for substitution among these fuels, but primarily because of technical and environmental considerations, the possibility of introducing other energy sources such as coal are very limited. As a result, producers of industrial chemicals are highly sensitive to availability and price adjustments of these fuels.

It should also be borne in mind that organics and inorganics often require fuels as both a feedstock and energy source, making supply and price conditions doubly significant to the viability of the sector.

Within the sector approximately 15 per cent of all non-feedstock energy consumed is committed to space heating, lighting and other accessory uses. The remainder is used as a process fuel generating steam and electrical power, heating feedstocks and operating driers, kilns and refrigeration units. The percentage distribution among the process uses varies with the particular output and method of production. The chlor-alkali process requires, for example, approximately 70 per cent of its total energy consumption to generate electrical power to operate electrolytic cells and compressors, 20 per cent for heating and drying of materials and 10 per cent for space heating, lighting and other purposes.

3.8.5 - The Future Outlook

Markets

The major chemical plant processes are so large that in most cases the market area for the products is much wider than provincial boundaries. This applies particularly to new petrochemical installations which must consider national and international markets for their output. Particular products are, of course, tied to certain industries such as ammonia which will be related to agricultural performance and chlor-alkali production which is related to pulp and paper production. On the other hand, the multiproduct organic streams are related to consumer spending and overall economic prosperity. Overall, markets will be related to general economic conditions in Canada and to some degree, North America, over the longer-term of the study.

Conservation

The Canadian Chemical Manufacturers Association, Canadian Fertilizer Institute and the Rubber Association of Canada have all initiated an active monitoring and conservation program. The estimate for industry wide reduction of unit energy requirements based on 1972 levels, is 17 per cent over the coming decade. These savings are divided equally over better plant operation and housekeeping, new capital expenditure, and improved technology. In Ontario the 17 per cent figure should be viewed as an upper limit since new plant installation may occur in Ontario at a slower rate than in other provinces, allowing less energy efficient methods of production to persist in Ontario. Provincially then a figure in the range of 12 to 15 per cent may be a more accurate estimate of the sector's conservation efforts to 1985.

Technology

New methods of production and improvements in existing techniques are constantly being introduced in chemical manufacture. But since literally all of this development is initiated outside of Canada, its introduction into the Canadian sector is slower and more irregular than is typical elsewhere, particularly in the United States. Further, the innovations are often typified by large-scale operations or other features which make them inappropriate to Canadian conditions. Thus additions to capacity will be met by world-scale plants. These infrequent additions will result in large bulges in output and energy consumption. Such a jump is anticipated for 1978 when the Petrosar complex is scheduled for start-up. Although some continuity in growth will

result from debottlenecking and adjusting levels of utilization of existing facilities, fuel consumption in this sector, and of natural gas in particular, will tend to be crisis-prone because of the irregular growth path arising from its large scale of production.

In terms of rapid changes in energy inputs per unit of product, no startling developments are foreseen and changes that do occur as a result of new technology are accounted for in the conservation estimations.

3.8.6 - Industry Model

The industrial chemicals classification includes all industries primarily engaged in the manufacture of inorganic and organic chemicals. The largest consumer of the products of this industry is the industry itself as the outputs or by-products of one process are consumed as the inputs of other processes in the same plant. In analyzing the industry, one is faced with many hundreds of products, only a small number of which have published output figures.

The industrial chemicals sector, for purposes of this study, has been divided into four overall processes. These are:

- Chlorine production,
- Ammonia and other inorganic chemical production,
- Ethylene production,
- Other organic chemical production.

The division of actual end products among these processes is:

	Inorganic		Organic
	Chlor-Alkali	Other	
Primary	Chlorine	Ammonia Zinc oxide Sulphuric and nitric acid Calcium carbide	Propylene Ethylene Butenes Benzene Toluene Xylenes
Inter-mediate		Urea Ammonia	Styrene Butadiene Ethylene oxide
End	Chlorine Caustic soda	Bulk fertilizers	Polyethylene Polyvinyl chloride Polystyrene Polypropylene

In the model prepared for this study we have selected only four elements as indicators of the total industry. These elements (ammonia, chlorine, ethylene and propylene) are considered to be first generation derivatives, i.e. they are the basic inputs to the industry. The production data for these elements was available on a national level but not provincial. Estimates of provincial output were obtained from various sources and are applied to the national data in the model in the form of proportions. These proportions are expected to decrease in many cases as new petrochemical facilities are completed in Western Canada, although total provincial production may not decline. The industry tends to be oriented to the ultimate market, i.e. it has been easier and less expensive to transport the raw materials (feedstocks) to the market areas for processing rather than the finished products.

In general the per unit energy requirements have been derived as the input per unit necessary to match the total energy consumed in the industry as listed by Statistics Canada. These totals to 1973 are:

Fuels Non-feedstock	Inorganic[1] -Chlorine -Ammonia	Organic -Ethylene -Propylene
(Ontario)	(Btu x 10^9)	
Coal	463.8	0.0
Natural gas	2,876.7	37,315.2
Fuel oil	17,633.4	10,657.8
Electricity	6,486.6	3,961.8
Feedstock		
(Canada)		
Natural gas	37,342.4	6,806.1
Fuel oil	110.6	1,491.8

Wherever possible the per unit figures are verified with operating statistics obtained in the literature and in the survey.

Chlorine

It has been assumed that 45 per cent of the total Canadian chlorine production occurs in Ontario.[2] The major consumer of chlorine is the pulp and paper industry; 56 per cent of total Canadian consumption was by this industry in 1973. Production has been related to the output of chemical wood

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[1] Data for the inorganic chemicals sector includes the relatively small amount of fuel (1,221.7 x 10^9 Btu) used by the pigment and dye industry.

[2] Thirty per cent of total Canadian production occurs in one Ontario plant.

pulp in Ontario (see section 3.14).

(8.1) ... $Qc = -148,137 + 0.221\ (PULPC)$

Chlorine production occurs in the presence of electricity and steam. Per unit energy requirements are 3,000 kwh and 9,680 pounds of steam per ton of chlorine.[1] This is a requirement for 10.2×10^6 Btu of electricity per ton for electrolysis, and 12.9×10^6 Btu per ton for steam. Chlorine plants often generate both electricity and steam on site. An example is one modern plant that uses three-quarters of its natural gas in gas turbines for electricity and the remainder in boilers for heat to supplement that from the turbines. However, no overall data could be obtained to quantify this relationship for the whole industry.

Ammonia

Ammonia production is expressed in tons of anhydrous ammonia. It is estimated that half of the productive capacity for ammonia is located in Ontario, the bulk of the remainder is in Alberta.[2] Consumption of the end-products of ammonia is centred in the agricultural sector. Thus production has been related to the provincial acreage (see section 3.2).

(8.2) ... $Qa = p_1\ (ACRES)$

where, p_1 is the ratio of ammonia production to total acres in Ontario. Over the 10-year period addressed in this study, the value of this parameter has risen from 0.031 in 1964 to 0.068 in 1973 (see Table 3.2a)

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1 The Conference Board, Energy Consumption in Manufacturing, energy requirements are for an electrochemical unit which is one ton of dry chlorine and 1.13-ton of caustic soda in 50% solution.

2 Corpus publishers, Feedstock Requirements for the Ontario Petrochemical Industries.

Natural gas is used as feedstock to the ammonia plants. Of the 34 to 36 million Btu[1] required to produce one ton of ammonia, two-thirds is assumed to be feedstock, the remainder is process heat.

Total feedstock requirements for Canada, listed by Statistics Canada as natural gas consumed as a material, indicates that 37.3×10^{12} Btu of natural gas were used in the inorganic chemicals sector. Given a total output of 1,372,659 tons of anhydrous ammonia (also Statistics Canada) we get 27.2×10^{6} Btu per ton which corresponds to the two-thirds figure above.

After removing the fuel consumption in the production of chlorine from the total fuel consumption in the inorganic chemicals sector, the remainder is assigned to ammonia production. This figure is more than enough to satisfy the process heat requirement for ammonia. The extra is assumed to include all other process requirements in the inorganic chemicals sector as well as other manufacturers in the industrial chemicals sector, e.g. pigment and dye industry. Output of anhydrous ammonia, therefore, serves as a proxy for all outputs of the sector.

Ethylene and Propylene

The demand for ethylene and propylene is reflective of the demand for all of their end-products.

Nearly 45 per cent of the Canadian ethylene consumption occurred in Ontario which amounted to some 405 million pounds in 1970.[2] In addition, it is estimated that over 250 million pounds of propylene were consumed in the

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[1] Acres' survey.

[2] Corpus, op. cit.

province. (No national or provincial time series for propylene was available.)

The current technology for the production of ethylene involves the use of a gas cracking process. The major co-product is propylene and the by-products are butadiene and the aromatics. The yields of this process reveal that for every pound of ethylene produced approximately one-half pound of propylene is produced. The actual yields by weight of ethylene range from 40 per cent of total output using a light naphta feedstock to 25 per cent using a heavy gas oil feed. The model computes energy consumption based on the ethylene output expressed in tons. The energy consumed to produce the co-product and by-products is included. The per unit energy consumption estimates are based on the Acres' survey and the literature.

Energy consumption for the myriad of the products of the organic chemicals sector uses the ethylene output measure as a proxy for total output. Therefore the per unit energy consumption figures are calculated in terms of the total activity in the sector associated with the output of one ton of ethylene, i.e. it includes all downstream energy consumption.

The list of final and intermediate products based on ethylene appears endless. They are consumed in virtually every sector of the economy. As such, they are related to Gross National Product.

(8.3) ... $Qe = -94,909 + 3.19 \text{ (GNP)}$

The data provided above for the organic chemicals sector is relevant to plant currently in use. The annual capacity of this plant is in the order of 500 million pounds.[1] A world scale ethylene plant, Petrosar, is nearing completion in the Sarnia area. This plant is capable of producing one billion pounds of ethylene per year as well as 700 million pounds of propylene and many other products. The project is actually a chemical refinery as its feedstock is crude oil and output is a wide range of primary chemical compounds.

The first stage -- the crude unit -- extracts a wide range of naptha from the oil and produces as by-products most of the outputs of a regular refinery, motor gasoline, No. 2 fuel oil and No. 6 fuel oil. The naptha is feed to the olefins plant where the ethylene is produced. Other products include methane, ethane, propane and propylene. The final stage -- the aromatics unit -- takes the pyrolysis gasoline from the olefins plant and produces gasoline and aromatics.

The energy forms used in the plant are electricity and steam. The steam is produced on site from the residual fuels produced during processing of the crude oil. Some 35 Mw of electrical power is required in the plant. This amounts to approximately $1,000 \times 10^9$ Btu per year or 2.0×10^6 Btu per ton of ethylene produced.

The feedstock and steam requirements will be nil as the fuel sources used are not addressed in terms of this study; in actual fact the quantities are immense:

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[1] Oilweek, June 21, 1976 and Corpus, op. cit.

Production Unit	Total Energy (Btu/year)	Btu per ton of Ethylene ($Btu \times 10^6$)
Crude	$4,855 \times 10^9$	9.71
Olefins	$16,800 \times 10^9$	33.60
Aromatics	344×10^9	0.69
Utilities	$3,158 \times 10^9$	-

Total feedstock is 61 million barrels of crude oil per year or 0.35×10^6 Btu per pound of ethylene product.

The per unit energy requirements matrix (Table 3.8b) lists fossil fuel requirements in the form of steam. These coefficients have been balanced with the process literature, the output measures of the major products for 1973 and the Statistics Canada energy consumption figures for 1973. On this basis, the inorganic sector's steam requirement would be fulfilled by coal (2.2%), natural gas (13.7%), and fuel oil (84.1%). The organic sector's steam requirement is fulfilled by fuel oil (22.2%) and natural gas (77.8%). These factors would be applied to the corresponding total steam requirements to obtain the total fossil fuel requirements for the sector.

The model considers only the fuel oil and natural gas used for ethylene and propylene production and not the requirements for petrochemical feedstocks (such as naptha, ethane, etc.) or their crude oil equivalents.

TABLE 3.8a

VARIABLES IN OUTPUT FORECASTING EQUATION

Year	Dependent Variables			Independent Variables		
(t)	(Qc)	(Qa)	(Qe)	(PULPC)	(ACRES)	(GNP)
1964	216,386	337,107	122,832	1,729,292	11,009,771	65,610
1965	256,092	368,682	132,554	1,787,607	10,995,994	69,981
1966	296,233	447,712	139,585	2,042,818	11,042,096	74,844
1967	315,152	533,448	145,569	2,184,629	11,070,018	77,344
1968	333,576	557,990	151,151	2,161,606	10,715,827	81,864
1969	375,668	602,748	173,530	2,260,131	10,401,211	86,225
1970	377,877	672,479	201,629	2,327,554	10,271,346	88,390
1971	383,485	705,985	208,818	2,318,150	10,080,495	94,115
1972	405,225	686,705	224,885	2,640,219	10,014,468	99,680
1973	441,519	686,330	245,410	2,645,824	10,120,789	106,845

where, Qc is 45 per cent of Canadian production of chlorine, in tons,

Qa is 50 per cent of Canadian production of anhydrous ammonia, in tons,

Qe is 45 per cent of Canadian production of ethylene, in tons,

PULPC is provincial production of chemical wood pulp, in tons (see Section 3.14)

ACRES is total provincial acreage (see Section 3.2)

GNP is Canadian Gross National Product in millions of constant 1971 dollars.

TABLE 3.8b

PER UNIT ENERGY REQUIREMENTS
INDUSTRIAL CHEMICALS

(Btu x 10^6/unit)[1]

Production Process (variable)		Energy Form: Feedstock: Fuel Oil	Natural Gas	Steam[2]	Electricity
Chlorine	(Qc)	-	-	12.9[3]	10.2[3]
Ammonia[5]	(Qa)	0.08	27.2[4]	22.2	2.8
Ethylene	(Qe)[8]	-	-	8.5[4]	3.9[4]
Other organic	(Qe)[8]	2.7[6]	12.5[6]	186.9[7]	12.2[7]
New Ethylene	(Qe)[8]	-	-	-	2.0

1 Units are tons of product.

2 1,333 Btu/lb (86% efficiency of production).

3 The Conference Board.

4 Acres' Survey.

5 Includes ammonia plus other inorganic chemicals.

6 Feedstock requirement based on Statistics Canada data for fuel oil and natural gas. These figures are less than the total feedstock data gleaned from the literature, the difference is categorized as petrochemical feedstock and propane which are not addressed in this study.

7 Statistics Canada data balanced to ethylene production data.

8 Ethylene demand is to be split based upon capacity.

3.9 - Iron Foundries

3.9.1 - Industry Overview - Energy Use

The iron foundry industry as defined here comprises firms listed exclusively as iron foundries and those listed as automobile parts manufacturers. The reason for this grouping is that a large number of the auto parts industries have foundry facilities integrated into their production facilities. The energy consumption in these facilities would have been lost if the iron foundry industry alone had been selected.

Total energy consumption in this sector for 1973 was 20.5×10^{12} Btu. This represents 2.5 per cent of the total industrial energy in that year. The energy demand is in the form of natural gas (51.6%), electricity (28.8%), fuel oil (12.9%) and small quantities of coal, gasoline and L.P.G. In addition to this purchased energy, it is estimated that some 90,000 tons of foundry coke was consumed in these industries in their various operations. This is included in the total energy consumption figure.

3.9.2 - Industry Overview - Markets

The output of this industry includes all cast iron items, such as motor housings, hydrants and manhole covers, iron pipe and fittings, valves and numerous other products. In the last decade the foundry industry has lost markets to forgings, fabricated rolled steel products, other cast materials such as aluminum and zinc, and to plastics. Despite a recent reversal in the declining growth rate of castings demand, the industry is still in a position

of excess capacity. In fact, most foundries operate only one shift per day.

3.9.3 - Production Process

There are essentially three energy-intensive processes in the foundry: cupola melting, electric melting and other operations including space heating, holding of molten iron, annealing and ladle warming.

A cupola is a cylinder in which coke is burned to melt iron. The cupola is charged with coke and iron from the top and fed with combustion air from the bottom. Energy in addition to that supplied from the coke is introduced to the cupola in the form of preheated combustion air or natural gas. Either method reduces the amount of coke required and reduces the need for costly pollution control equipment.

The melting process has two phases, the preheat and melt (to 2300°F) and the superheating phase (2300°F to 2700°F). The cupola loses efficiency as the temperature of the molten iron increases. It is estimated that the cupola transfers 60 per cent of the heat potential in coke to the iron during preheating and melting, but only seven per cent during superheating. [1]

Electric induction furnaces present an alternative to the cupola. Their introduction was delayed for many years by the sluggish demand for iron castings coupled with the over-capacity problem. The demand for malleable iron for

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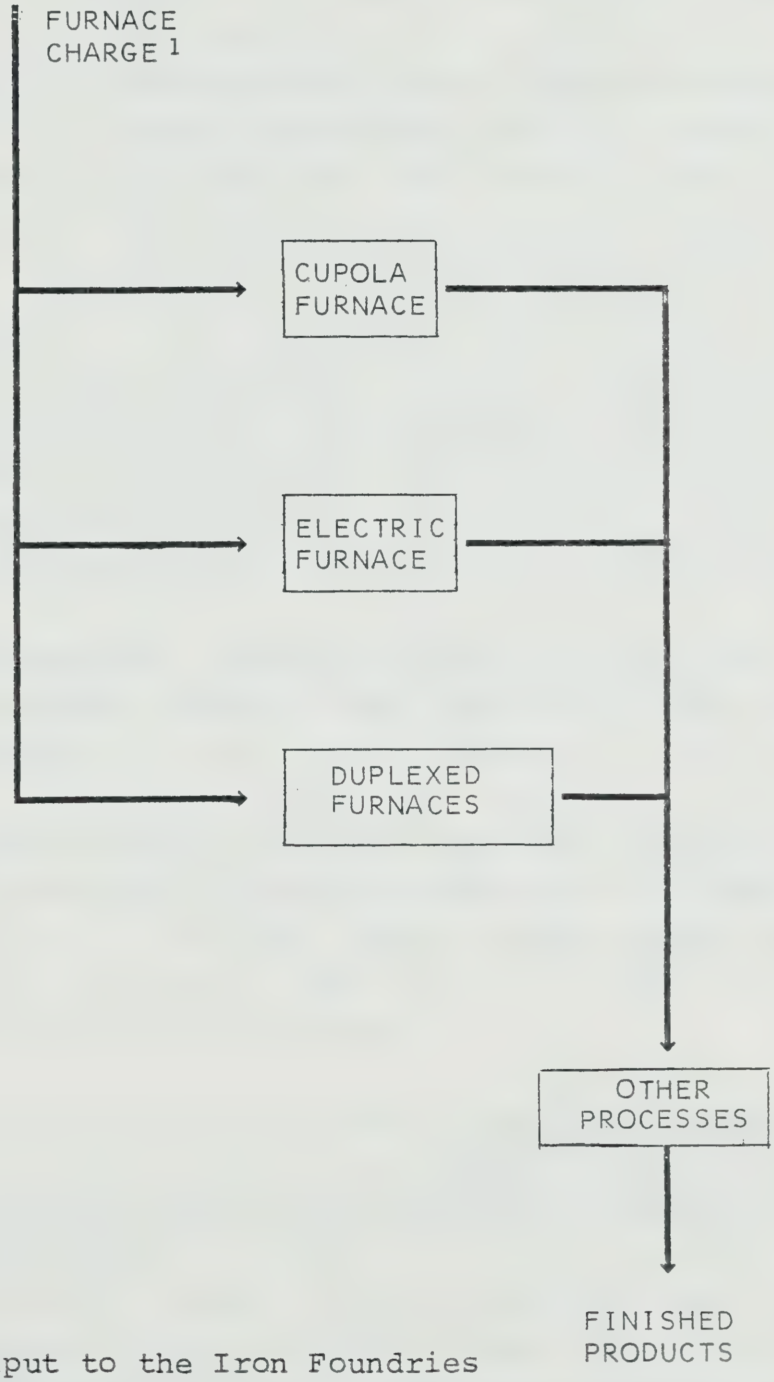
[1] Ontario Hydro Study, Energy Use in the Iron Foundry Industry in Ontario.

PRODUCTION PROCESS
IRON FOUNDRIES



[1] Pig iron input to the Iron Foundries Industry consumes no energy in the sector. Energy consumption in the production of pig iron is assigned to the Iron and Steel Industry.

automotive and plumbing parts imposed temperature control and metallurgical composition requirements on the industry which could not be satisfied by the cupola. Thus the electric furnace was forced into operation.

The electric furnace is equally efficient in the two melting phases, at about 60 per cent efficiency. The extent to which electric furnaces are likely to replace cupolas depends, in addition to the quality considerations mentioned above, on comparative economics. The electric furnace is more efficient than the cupola in the superheating phase. It is in this area that it has found its greatest use. Duplexing, i.e. using the cupola for the melting phase and electric furnace for the superheating is gaining more favour in the industry as fossil fuel and coke prices rise in relation to electricity charges.

The electric furnace also is capable of melting lower cost raw materials such as steel and iron scrap, is more compatible with automated pouring lines and alleviates many pollution problems. The major drawback to an all-electric installation over a cupola system is cost. It is estimated that the electric furnaces cost 70 per cent more than the equivalent cupola system.

3.9.4 - Energy Consumption

Electricity and natural gas are the main energy sources in the industry, electricity finding its major use, of course, in the electric induction furnace, while natural gas is used in the cupola to offset coke consumption, and for other foundry operations such as space heating and

ladle warming. The distribution of total energy consumption in the industry (excluding foundry coke consumption) is estimated below:

Metal melting	25.1%
Metal holding	6.6
Other foundry uses[1]	31.0
Space heating	30.4
Services	6.9
	100.0%

The survey revealed few opportunities for direct fuel substitution. Natural gas is currently fired in the cupola to replace coke, this has reduced the amount of coke consumed from 335 pounds to 250 pounds per ton of iron.[2] Approximately 500 cubic feet of gas is used in the substitution. Other factors also encouraged the substitution such as pollution control and closer temperature control.

These same factors contributed to the increasing use of electric furnaces which has resulted in a substitution of electricity for coke. While it appears from the survey that most replacement furnaces will be electric, no timing was available for this change.

Substitution for natural gas in other operations such as space heating or ladle warming appear possible but only if equipment permits. No dual fuel capability was found in these areas.

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1. Includes heat treating, annealing, ladle warming, material handling, etc.

2 The Conference Board, Energy Consumption in Manufacturing Manufacturing.

3.9.5 - The Future Outlook

Markets

Lower weight requirements in automobiles are expected to reduce the demand for cast iron items. Other markets for the industry should remain relatively stable with moderate growth.

Conservation

Apparently there are no conservation programs within the industry other than those dictated by energy costs. More efficient use of waste heat at both the cupola and ladle warming system are obvious areas for attention.

Technology

The only technological change in the industry is the potential to phase out the cupola in favour of the electric furnace. The immediate effect of this change would be a reduction in foundry coke consumption and some natural gas use. The long run effect would depend on the extent and timing of electric conversion.

3.9.6 - Industry Model

Four processes have been identified in this industry; three deal with the melting operation, the fourth with all the operations in the foundry:

- Cupola furnace melting,
- Electric induction furnace melting,
- Duplexed furnace melting, and
- Other foundry operations.

Production in the Ontario iron foundry industry, which includes automobile part manufacturers, was measured in terms of the total tons of iron castings produced in a given year. The actual volume of castings was estimated based on the relationship of the provincial value of shipments to the Canadian value and expressed in tons, i.e. the Ontario value was divided by the national value and this proportion multiplied by the total Canadian tons of iron castings to obtain the provincial output in tons.

The output has been related to the output of automobiles in North America and to the Canadian Gross National Product in millions of constant 1971 dollars. The first of these variables reflects the industry's major market and the second reflects all other markets.

(9.1) ... $Q_t = 53{,}642 + 0.07 \ (AUTOP) + 2.82 \ (GNP)$

Output is then assigned to the three melting processes: cupola, electric and duplex, according to parameters reflecting estimates of current operations.

(9.2) ... $q_1 = p_1 Q_t$, output from cupola furnaces

(9.3) ... $q_2 = p_2 Q_t$, output from electric furnaces

(9.4) ... $q_3 = p_3 Q_t$, output from duplexed furnaces

The proportions were estimates based on information in an Ontario Hydro report on the iron foundry industry. This report states that approximately 80 per cent of the iron castings are melted by cupola furnaces. Virtually all of the remainder used an electric furnace. Duplexing which consists of melting in cupolas and superheating in

electric furnaces is included in the above. We have estimated that 60 per cent of the total output is from cupola-based furnaces, 20 per cent from all-electric shops and 20 per cent from duplexing furnaces. Thus, $p_1 = 0.6$, $p_2 = 0.2$ and $p_3 = 0.2$.

TABLE 3.9a

VARIABLES IN OUTPUT FORECASTING EQUATION

Year	Dependent Variable	Independent Variables	
(t)	(Q_t)	(AUTOP)	(GNP)
1964	802,115	8,293,600	65,610
1965	952,468	9,996,586	69,981
1966	971,582	9,292,381	74,844
1967	905,331	8,150,848	77,344
1968	934,269	9,714,007	81,864
1969	961,415	9,260,490	86,225
1970	833,566	7,488,310	88,390
1971	917,092	9,679,645	94,115
1972	993,227	9,982,377	99,680
1973	1,206,832	10,903,218	106,845

where, Q_t is estimate of output of iron castings in Ontario in tons, Source: Statistics Canada 41-004, Acres,

AUTOP is total output of automobiles in North America, Source: Canadian Motor Vehicle Manufacturers Association,

GNP is Canadian Gross National Product in millions of constant 1971 dollars, Source: Statistics Canada.

TABLE 3.9b

PER UNIT ENERGY REQUIREMENTS
IRON FOUNDRY

(Btu x 10^6/unit)[9]

Production Process (variable)	Energy Form: Fuel Oil	Natural Gas	Coal[11]	Electricity
Melting Furnace:				
Cupola (q_1)	1.0[5]	2.0[10]	5.00[2,4,6]	-
Electric (q_2)	1.0[5]	-	-	2.10[1,3,]
Duplex (q_3)	1.0[5]	2.0[10]	2.20[2,4,6]	.27[3,4]
Other operations (Q_t)	.95[7]	6.1[7]	-	3.98[8]

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1 Based on 600 kwh/ton, Ontario Hydro.

2 Cupola is 60 per cent efficient in melt and 7 per cent in superheating phase, Source: Ontario Hydro.

3 Electricity is 60 per cent efficient in both melt and superheating phase, Source: Ontario Hydro.

4 Melt phase consumes 87 per cent of heat, superheating phase only 13 per cent, Source: Ontario Hydro.

5 Acres Survey.

6 One ton of coke equals 1.44 tons of coal. This conversion factor is obtained at the coke ovens in the iron and steel mills. Consistency with that sector (Section 3.10) should be maintained.

7 Space heating, annealing, paint drying.

8 Lighting, materials handling.

9 Units are tons of iron castings.

10 Includes ancillary operations; ladle warming, combustion air preheaters, etc.

11 Non-coking coal used for cooling is not considered in the model.

3.10 - Iron and Steel

3.10.1 - Industry Overview - Energy Use

In 1973 Ontario's iron and steel industry consumed 58.3×10^{12} Btu of energy. This represents 10.6 per cent of Ontario's 1973 total purchased industrial energy consumption. Though the total energy requirements of the iron and steel industry are very large, the application of standard measurements of energy-intensiveness place this industry well below the leaders. Fuel sources for this industry are natural gas (60%), oil (18%) and electricity (22%).

An additional energy input to this industry is the feedstock coal used to form metallurgical coke. In 1973, this input was in the order of 128.0×10^{12} Btu. This modifies the above energy proportions to coal (69%), natural gas (19%), electricity (7%) and fuel oil (5%).

The requirements for individual forms of energy per unit of output in this industry can be viewed as relatively fixed because only very limited interchangeability of fossil fuels is possible.

3.10.2 - Industry Overview - Markets

The market for Ontario steelmakers is primarily domestic. Most of the major producers , in fact, give priority to domestic customers, especially in times of heavy demand. The export market is important to take up production surplus to domestic demands and this is often successfully accomplished because of the Canadian steelmakers'

relative efficiency. In the past few years, exports of steel from Canada have dropped from 14.4 per cent of production in 1970 to 8.2 per cent in 1975.

CANADIAN SHIPMENTS AND EXPORTS OF ROLLED STEEL PRODUCTS

	Total Canadian Shipments	Total Exports	Export Proportion
	(net tons of 2,000 lbs.)		(%)
1970	9,084,605	1,310,245	14.4
1971	9,220,748	1,210,127	13.1
1972	9,829,866	1,174,398	11.9
1973	10,935,708	990,429	9.1
1974	11,439,226	1,011,480	8.8
1975	10,452,097	860,727	8.2

Source: Statistics Canada 41-001

Ontario's three major integrated steel producers are in various stages of adding steelmaking capacity. Though the ultimate size of these additions is open to question (a reasonable estimate being that present capacity will be doubled), the significant observation concerning additions to capacity is that all are committed to the traditional method of making steel. Technology employed consists of blast furnaces and basic oxygen steel furnaces. This means that traditional technology still is and is expected to continue as the most economic means of adding substantial capacity. The only serious challenge to this method of steel production is the direct reduction -- electric furnace process. The viability of this alternative rests in the relationship between the availability and price of coking coal versus that of electricity.

3.10.3 - Production Process

The Ontario steel industry consists of fully integrated major steel producers such as Algoma, Dofasco and Stelco, and of specialty producers such as Lasco, Burlington Steel and Atlas Steels. On a volume basis, the integrated steel industry accounts for over 90 per cent of the Ontario production. From the energy consumption point of view there are significant differences between the "majors" and the "minors".

The majors, the integrated steel industry, produce steel starting with iron ore, making molten iron in a blast furnace and finally changing iron to steel in either an open hearth or a basic oxygen furnace. Thereafter the molten steel is cast into ingots or slabs and then the finishing processes begin.

Whereas the integrated major steel industry starts the steelmaking process with iron ore, the specialty steel industry cuts the process short by starting with iron and/or steel scrap. This short-cut is highly significant in terms of energy requirements per ton of product. If all new steel requirements could be met through the recycling of used steel, the total energy requirements of the integrated steel industry would decrease drastically.[1] However, the supply of scrap is such that no more than 30 to 35 per cent of the steel furnace charge can be met from this source.

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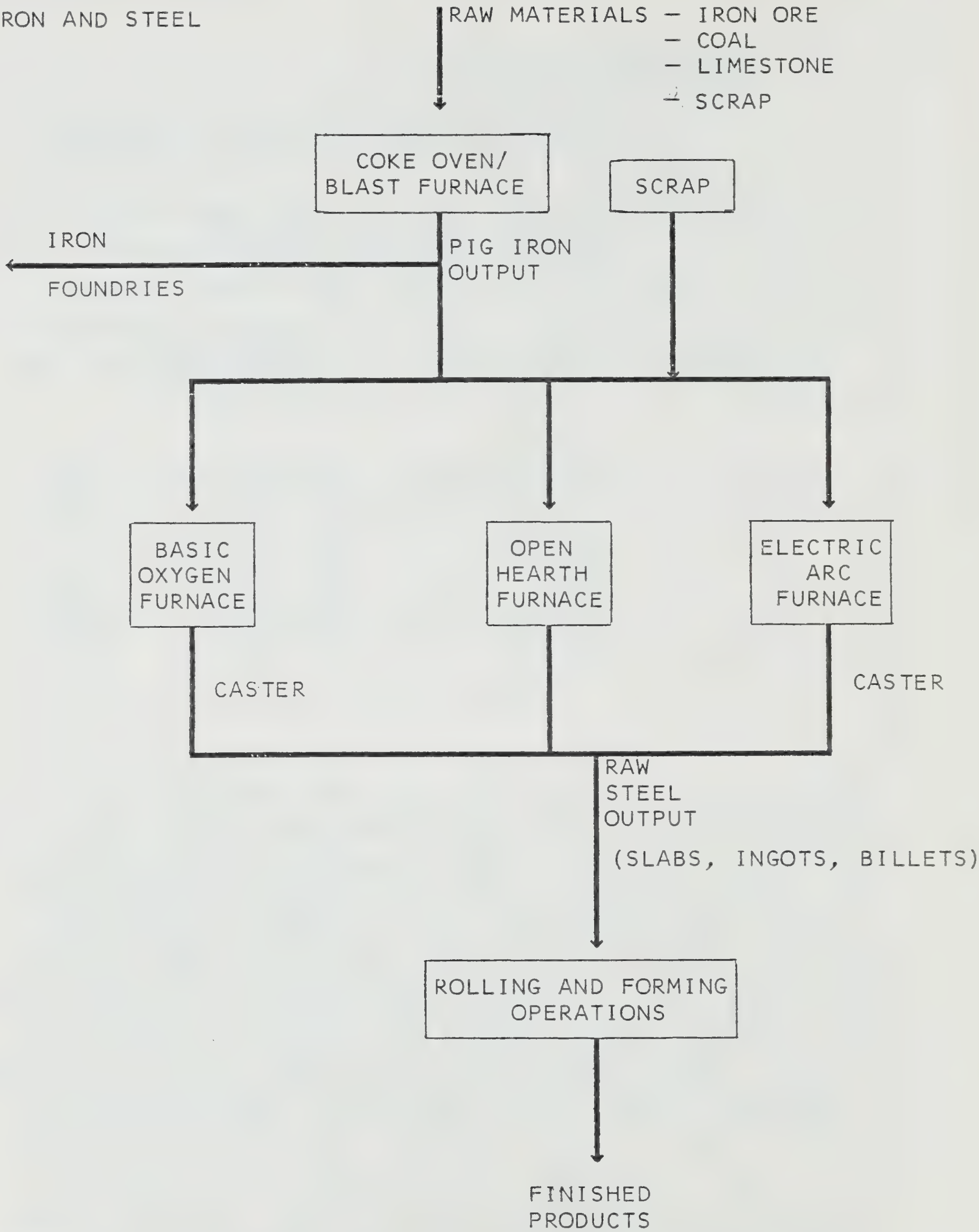
[1] EM&R, Canada (Minerals Division) estimate that electric steelmaking which is based on 100 per cent scrap, consumes approximately 6.2 x 10^6 Btu per ton, traditional steelmaking using blast furnaces and open hearth or basic oxygen steelmaking furnaces which are based on less scrap and consume 19.9 and 21.4 x 10^6 Btu per ton respectively.

PRODUCTION PROCESS
IRON AND STEEL



A brief description of energy utilization within the steel industry is, at best, difficult. The problem is that each major mill has developed and based its process technology on an individualistic use of the various fuel available, e.g. oil, natural gas, coke oven gas, blast furnace gas, electricity, etc. Thus a statement made concerning some specific use of one form of energy may only apply to one producer instead of to all. To complicate matters even further, the product mix of the many producers is different.

An industry overview would isolate the following major processes:

1. <u>Smelting iron ore into pig iron in a blast furnace</u>

   Coke, produced in on-site coke ovens is the major heat source as well as the principal reductant. An important by-product of coke, coke oven gas, containing some 500 Btu per cubic foot is used in combustion to reduce purchases of fossil fuels for blast furnace and steelmaking operations. Blast furnace gas, the exhaust from the blast furnace, is also used for the same purpose. Approximately 3 million Btu of coke oven gas and 4 million Btu of blast furnace gas are used per ton of raw steel produced.

2. <u>Refining pig iron and scrap into steel</u>

   The pig iron leaving the blast furnace may contain up to 4.5 per cent carbon and lesser quantities of silicon, manganese, phosphorous and sulphur. To produce steel, these contaminants must be reduced, carbon content dropping to 0.4 per cent for a typical high

carbon steel and to 0.1 per cent for a typical low carbon steel.

Three major types of furnace are available:

<u>The open hearth furnace</u>: This is a long and shallow bath which is heated by radiation and convection from a flame which sweeps above the metal in the hearth of the furnace. Fuel may be natural gas, coke oven gas, fuel oil, tars or combinations of these. The furnace charge consists of pig iron, scrap and flux. Molten pig iron is normally used from nearby blast furnaces and is charged directly to the furnace minimizing the energy required to heat the charge.

The energy supply to the open hearth furnace comes almost entirely from the fuel. The process is not dependent on thermal energy derived from the oxidation of elements dissolved in the metal, as is the case with the basic oxygen furnace. Oxygen is introduced to the open hearth furnace to increase output capacity.

The scrap/pig iron mix can be flexible for the open hearth up to an economic limit of 70 per cent scrap charge. The practical limits of availability keep the actual scrap content far below this figure. A typical Canadian average is in the order of 35 per cent.

<u>The basic oxygen furnace (BOF)</u>: The basic oxygen furnace is a cylindrical brick-lined vessel. Molten pig iron and scrap are charged into the furnace and oxygen is introduced into the charge through a lance.

Unlike the open hearth and electric furnaces, the basic oxygen furnace does not require any supplementary source of heat. The thermal energy comes substantially from the oxidation of carbon and other impurities, notably silicon. Though scrap content in a normal BOF charge is in the order of 20 to 30 per cent, preheating of scrap allows a larger proportion to be used, with the technical limit being in the order of 50 per cent.

The electric furnace: At the present time the electric furnace is not widely used in Ontario by the major integrated steel companies. It is used by the specialty iron and steel industry.

The electric furnace has an advantage over the open hearth and basic oxygen furnaces in making alloy steels because conditions can be very carefully controlled. Scrap is used almost exclusively as a charge to electric furnaces.

3. Semi-finishing of molten steel

Molten steel from the steelmaking furnaces is either poured into ingots and rolled into slabs, billets or blooms, or it is continuously cast into slabs, billets or blooms and rolled to shape. In the former case, the ingots are heated to a uniform temperature in soaking pits prior to rolling. In the latter case, the slabs, billets and blooms are reheated prior to rolling.

3.10.4 - Energy Consumption

It was stated earlier that the dominant source of energy in the integrated steel industry is coal, which accounts for some 69 per cent of the total energy consumption. Oil, natural gas and electricity account for 5, 19 and 7 per cent respectively. The specialty steelmakers depend primarily on natural gas and electricity for their electric furnaces. The integrated steelmakers depend upon the direct application of fossil fuels in the production of steel. Since the three fossil fuels used (i.e. coal, natural gas and fuel oil) all have different characteristics, it becomes difficult to totally substitute one fuel source for another within the same equipment. Apart from coal, there is no generally required fossil fuel in the integrated steel industry. Each mill has developed its own processes and over the years has come to require a unique mixture of fossil fuels. Theoretically, shifts from use of natural gas to oil or from oil to gas are possible. Yet in practice such moves would cost millions of dollars and take years to accomplish.

Presently, the integrated steel industry uses approximately 21.5 million Btu to produce and process one ton of saleable raw steel.[1] According to the International Iron and Steel Institute, the most efficient energy utilization in a modern steel mill using traditional technology should result in an energy use approaching 17.5 million Btu per ton. Here, the grade of the ore and of the coal available to each mill plays a significant role in determining actual energy requirements.

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[1] This figure includes all purchased fuels, coal, fuel oil, natural gas and electricity.

3.10.5 - The Future Outlook

Markets

Over the long-run the Canadian steel industry is likely to remain primarily oriented to domestic markets. Thus Canadian prosperity and growth in general will play a large part in determining output levels. Such factors as car sales and construction will play a role in determining this demand and have been built into the model. To some degree, product mix may change over the study period but basically steel will remain one of the industrial foundations of consumer goods manufacture over the period and no startling changes in the growth pattern arising from substitutions are likely to occur.

Conservation

Only a relatively modest potential exists in this industry for the reduction of energy use per unit of output even with large expenditures. At the Second Conference on Industrial Energy Conservation, the industry forecast a reduction in average energy consumption per ton of raw steel from the present 21.5 million Btu to 20.8 million Btu by 1980. This reduction is predicated, amongst other things, on the successful completion of planned expansion and operation at high levels of capacity utilization. Much will depend on the quality of both the iron ore and coal available.

One aspect of the operation of high temperature processes such as steel production is not generally recognized. Often there exists potential for the generation of steam that could be used either for heating or for the generation of electricity. Such steam and electricity would be

surplus to the requirements of the industry and unless markets were to be developed for this surplus energy, there would be no point in considering its generation. From the overall efficiency point of view, it would appear prudent to explore such excellent opportunities for the better utilization of energy. No estimate of current or future generation was obtained in this study.

Technology

In a very capital-intensive industry such as this, technological breakthroughs do not occur frequently. The magnitude of the initial investment by itself, tends to decrease the possibility of experimenting with smoothly running plants because the cost of repairing possible damage would be measured in the millions of dollars. For that reason alone, new technology cannot be accepted until it is fully proven in pilot plants, again at the expenditure of vast sums of money.

Expansion in the steel industry will involve greater use of the BOF rather than the open hearth which has been considered to be obsolete in the past 10 years. There is also an increase in the use of electric furnaces. This should tend to have a positive effect on the availability of scrap. The overall trend indicates that open hearth furnaces will be phased out based on the better economics of basic oxygen and electric furnaces. However, it is difficult to predict the timing of this substitution. EM&R use the period between 1980 and 1985 for the phasing out of the open hearth furnace.[1]

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[1] EM&R, Operators List 2, January 1975.

The Canadian steel industry is generally considered as one of the most efficient in the world. In view of the above statement it is relevant to note that although there are such developments as direct reduction, the combination of economics and confidence in the new technology has made the industry approach the investment of millions of dollars in such technologies with great caution. If they become viable and there is every indication that direct reduction is, the installation of new capacity which will last for 20 or 30 years, makes the wide application of the new technology unlikely within the time frame of this study.

In direct reduction, high grade iron ore is pelletized and fed to the reduction furnace. The output from this furnace is the charge to an electric arc steelmaking furnace. Fuel for the reduction furnace can be non-coking coal, natural gas or other gas, electricity is the obvious power for the steelmaking phase. Reduced iron ore pellets offer a viable substitute to scrap for the existing electrical steel producers in Ontario. In order for the direct reduction process to compete with traditional iron and steel production processes, there must be high quality ore available, an abundance of low-cost non-coking coal, low-cost electricity, a shortage of coking coal and an uncertain scrap market.

Two processes are currently in use in Canada or under investigation. The Mildrex process uses gas to reduce the ore while the SL/RN process is based on low quality non-coking coal.

Energy requirements, based on internal Acres' documents are estimated at 13.9 x 10^6 Btu per ton for the Mildrex

process and 9.2 x 10^6 Btu per ton for the SL/RN process. Both would require approximately 120 kwh of electricity per ton.

One final technological development that could have significant impact on the energy mix in steelmaking is the application of nuclear energy. The concept here is not to change the basic steelmaking technology but to apply thermal nuclear electric power to a major steelmaking plant as the primary energy source and thus replace many of the conventional fuel sources. The magnitude of such an undertaking, however, probably excludes it from being done by a steelmaker. More likely it would be a joint effort of a major utility such as Ontario Hydro and a steelmaker who would take a major base load of the plant while the remainder would be sold to other customers. In the long-run, this would clearly affect, in a major way, the demand of the steel industry for fossil fuels (oil and gas). Coal would be the only fossil fuel required in the industry and that only because of its metallurgical properties.

An alternative use for nuclear power, and a far more ambitious project, is to apply the heat of a nuclear reaction directly to the iron and steelmaking process. This definitely has a long lead time associated with it and will probably not be a factor within the study period covered here. The advent of nuclear energy in steelmaking will no doubt be further off than widespread investment in direct reduction.

3.10.6 - Industry Model

The model for the iron and steel sector has not divided the industry into the traditional integrated versus specialty steel classification but has rather opted for an approach which isolates the process regardless of the type of mill in which it is located.

For the purposes of this study the energy-intensive processes have been identified as:

- Blast furnace/coke oven,
- Basic oxygen furnace (BOF),
- Open hearth furnace (OH),
- Electric arc furnace,
- Finishing (rolling, forming, extruding, etc.)

Purchased fuel consumption in the traditional steel industry is supplemented to a great degree by gases from the blast furnace and the coke ovens. Blast furnace gas (95 Btu/scf)[1] is used to heat the air required for combustion in the blast furnace itself. Forty per cent of the available coke oven gas (500 Btu/scf)[1] is reused in the ovens; the remainder is consumed in other processes in the plant.

Energy used for processes in the mills other than those listed above is included in the finishing process.

Production data in the iron and steel industry was numerous. However, it tended to be available only at the national level with scattered data and information on a provincial basis.

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[1] scf - standard cubic foot (60°F - 1 atmosphere)

The only readily available provincial measure was the total output of steel ingots and castings expressed in tons. The input to the model required a breakdown of this total by steelmaking furnace and this was available at the national level. Fortunately, the distribution of furnaces in Canada allowed a reasonable estimate of Ontario production.

All basic oxygen furnaces are located in Ontario and only one open hearth operation is outside of the province. The production figures for this single operation was listed in an EM&R publication[1] and thus Ontario data could be computed for open hearth steelmaking. Electric furnace output was taken as the remainder.

Total output of steel ingots and castings is forecast based on two economic variables: Gross National Product in millions of constant 1971 dollars and total Ontario auto output.

(10.1) ... STEEL = 2,279,372 + 63.6 (GNP) + 2.09 (OAUTO)

This output must be assigned to the three steelmaking furnaces currently in use in the province. The three parameters will change over time to reflect the changes in the industry, e.g. phasing out of open hearth operation in favour of basic oxygen and electric.

(10.2) ... Qoh = p_1 (STEEL)
= output tons of open hearth process, current (1973) value for p_1 is 0.315

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1 Canadian Primary Iron and Steel Statistics to 1971.

(10.3) ... Qbof = p_2 (STEEL)
= output tons of basic oxygen process, current value for p_2 is 0.617

(10.4) ... Qel = p_3 (STEEL)
= output tons of electric process, current value for p_3 is 0.068

A large shift to direct reduction techniques would increase the demand for electric furnace facilities. However, no long-term forecast of direct reduction facilities was available and this impact could not be assessed.

The yields of each process that is the relationship between the output of the process and the input in terms of weight, are an important consideration in this industry. The data was obtained from internal Acres' files. The yield of an electric furnace charged with scrap was taken to be representative of the scrap to steel yield in all furnace types. The pig iron to steel yield was computed after the scrap input was taken into account. The final yield, that of the finishing process, was taken directly from EM&R. The yields computed were:

y_1 = 0.909, open hearth furnace steel output to pig iron input ratio,

y_2 = 0.847, basic oxygen furnace steel output to pig iron input ratio,

y_3 = 0.877, electric furnace steel output to scrap input ratio; this figure was also assumed to be the steel output to pig iron ratio for electric furnaces and the steel output to scrap ratio for all furnaces,

y_4 = 0.77, finishing process output to raw steel input ratio.

Scrap input into the various steelmaking processes has a great impact on total energy consumption. An increase in the scrap input reduces the pig iron requirement for the same output quality. This, in turn, would reduce the total coke consumption in the blast furnace and total coal consumption in the coke oven process.

Open hearth steelmaking furnaces can theoretically accept up to 70 per cent scrap in the charge. Basic oxygen furnaces depend upon the impurities in the pig iron for much of the heat energy in the process and so must accept a lower percentage of scrap. The maximum is 50 per cent. The current scrap input of these furnaces is approximately 35.5 and 28 per cent respectively. The electric furnaces can and do accept 100 per cent of their charge in the form of scrap. (Some pig iron is often included but the amount is negligible.) The scrap ratios used in the model are s_1 for open hearth furnaces, s_2 for basic oxygen furnaces and s_3 for electric.

The model computes the tons of scrap and pig iron input using the yields and the scrap ratios. For example, assume the total output of raw steel from basic oxygen furnaces is computed as 500 tons. The scrap input ratio is 28 per cent and the yield of scrap is 87.7 per cent and of pig iron 84.7 per cent. Scrap input in tons would be:

$$\begin{aligned} \text{SCRAP} &= 500/(y_2 \times ((1 - s_2)/s_2) + y_3) \\ &= 500/(.847 \times ((1.0 - .28)/.28) + .877) \\ &= 163.7 \text{ tons.} \end{aligned}$$

Pig iron input is based on its relationship to the scrap

input ratio (s_2):

$$\text{PIG IRON} = 163.7 \times ((1 - s_2)/s_2)$$
$$= 163.7 \times ((1.0 - 0.28)/0.28)$$
$$= 420.9 \text{ tons.}$$

An additional check is made in the model to ensure that the values of s_1, s_2 and s_3, the scrap input ratios, do not exceed the theoretical values mentioned above.

Thus, inputs to open hearth process:

(10.5) ... $q_1 = Qoh/(y_1 \times ((1 - s_1)/s_1) + y_3)$
= tons of scrap

(10.6) ... $q_2 = q_1 \times ((1 - s_1)/s_1)$
= tons of pig iron,
where the theoretical maximum value for s_1 is 0.70, current value is 0.355

Inputs to basic oxygen process:

(10.7) ... $q_3 = Qbof/(y_2 \times ((1 - s_2)/s_2) + y_3)$
= tons of scrap

(10.8) ... $q_4 = q_3 \times ((1 - s_2)/s_2)$
= tons of pig iron,
where the theoretical maximum value for s_2 is 0.50, current value is 0.28

Inputs to electric furnaces:

(10.9) ... $q_5 = Qel/(y_3 \times ((1 - s_3)/s_3) + y_3)$
= tons of scrap

(10.10) ... $q_6 = q_5 \times ((1 - s_3)/s_3)$
= tons of pig iron, where theoretical maximum value for s_3 is 1.0, current value is 1.0.

Total tons of finished steel products is based on the production of raw steel:

(10.11) ... $Qf = y_4$ (STEEL), current value of y_4 is 0.77.

For simplicity, the model assumes that the furnace charge is segregated into the two major components, scrap and pig iron, and in effect charged to separate furnaces. This, of course, does not happen but serves only to allow modifications to the scrap charge by furnace type.

Total production of pig iron[1] is:

(10.12) ... $IRON = (q_2 + q_4 + q_6) \times (1 + y_5)$

The study revealed that some of the blast furnaces were supplemented with natural gas while others used fuel oil. The Ontario Hydro Study figures lead to the assumption that 51 per cent of the blast furnaces were supplemented with fuel oil. Furnace output is computed as:

(10.13) ... $Qif = p_4$ (IRON), fuel oil supplement, and

(10.14) ... $Qig = (1 - p_4)$ (IRON), gas supplement, where the current value of p_4 is 0.51.

The coal consumption figure listed in Table 3.10b is based upon the current values of the coke rate (the amount of

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1 Variables q_2, q_4 and q_6 represent the amounts of pig iron required for steel furnaces only. Pig iron is also required as input to the Iron Foundry Industry. On a national basis this input represented 3.6 per cent of the total pig iron charged to steel furnaces (1971-1973). The current value of y_5 is thus assumed to be .036.

coke required per ton of pig iron) and the coke oven yield (the amount of coal required per ton of coke). American data presented by Gordian Associates and The Conference Board[1] show the coke rate to be declining:

Year	Coke (lbs)	Coke Rate (ton/ton)
1913	2,173	1.087
1947	1,926	0.963
1961	1,416	0.708
1962	1,380	0.690
1963	1,338	0.669
1964	1,310	0.655
1965	1,312	0.656
1966	1,282	0.641
1967	1,262	0.631
1968	1,248	0.624
1969	1,252	0.626
1970	1,260	0.630
1971	1,254	0.627
1972	1,230	0.615

Several reasons for the reduced coke rate were provided:

1. Conversion to pelletizing,
2. Improved operating practice,
3. Larger blast furnaces,
4. Higher blast temperatures,
5. Hydrocarbon fuel injection.

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[1] Gordian Associates, The Potential for Energy Conservation in Nine Selected Industries.

The Conference Board, Energy Consumption in Manufacturing.

The savings of a reduced coke rate were quantified per ton of raw steel in the Gordian study.[1] The savings associated with a 0.1 ton reduction in coke use per ton of pig iron by means of items 1 to 4 is 1.38×10^6 Btu per ton of raw steel. If the savings are based on hydrocarbon injection instead (item 5), the saving is 0.56×10^6 Btu per ton of raw steel.

No theoretical minimum coke rate was provided although, because the coke is required for its metallurgical properties as well as its heat content, there must be some minimum. The Conference Board suggests a coke rate of 0.5 in its projection to 1980. The same sources, verified by Statistics Canada data, specify that 1.44 tons of coal are required to produce one ton of coke. This has remained relatively constant over the past decade. The per unit energy requirement is based on a coke rate of 0.615 and a coal/coke ratio of 1.44.

Changes in the grade of iron ore will have no effect upon the iron and steel mills postulated in this model. The model is based on blast furnace burden composed of pelletized iron ore which contains a uniform percentage iron (approximately 66 per cent). The impact of a lower grade of ore would be at the mining/pelletizing level. Currently the ore is 19 to 55 per cent iron. Estimates from EM&R of energy consumption in this phase are 6.6 gallons of fuel oil or 0.92 mcf of natural gas and 96 kwh per ton of pellets. Recent Statistics Canada data indicate a ratio of approximately 1.33 tons of ore pellets per ton of pig iron.

The energy used for the mining and pelletizing of iron ore has not been included here but rather is included in the mining, milling, smelting and refining sector.

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[1] Gordian Associates, Ibid, Steel, p.109-110.

TABLE 3.10a

VARIABLES IN OUTPUT FORECASTING EQUATION

Year (t)	Dependent Variable (STEEL)	Independent Variables (GNP)	(OAUTO)
1964	7,581,251	65,610	539,572
1965	8,485,219	69,981	687,672
1966	8,453,480	74,844	690,354
1967	8,333,431	77,344	709,733
1968	9,400,741	81,864	886,179
1969	7,960,199	86,225	1,019,600
1970	10,129,433	88,390	919,469
1971	10,010,166	94,115	1,074,370
1972	10,768,167	99,680	1,137,832
1973	12,040,019	106,845	1,224,117

where, STEEL is total tons of steel ingots and castings produced in Ontario, Source: Statistics Canada 41-203

GNP is Canadian Gross National Product in constant 1971 dollars, Source: Statistics Canada,

OAUTO is total output of motor vehicles in Ontario, number of units, Source: Canadian Motor Vehicle Manufacturers Association.

TABLE 3.10a (cont'd)

ESTIMATES OF OUTPUT - IRON AND STEEL
1964 - 1973

(tons)

Year	Total Steel Ingots & Castings[1]	Basic Oxygen Furnace[2]	Open Hearth[3]	Electric Furnace[4]
(t)	(STEEL)	(Qbof)	(Qoh)	(Qel)
1964	7,581,251	2,785,482	4,405,300	390,469
1965	8,485,219	3,232,572	4,685,900	566,747
1966	8,453,480	3,377,733	4,467,300	608,447
1967	8,333,431	3,208,655	4,514,700	610,076
1968	9,400,741	3,509,038	5,320,500	571,203
1969	7,960,199	3,275,297	4,286,100	398,800
1970	10,129,433	3,617,985	5,902,500	608,948
1971	10,010,166	3,934,965	5,437,800	637,401
1972	10,768,167	5,601,287	4,364,600	802,280
1973	12,040,019	7,433,896	3,797,200	808,923

[1] Statistics Canada, 41-203.

[2] EM&R, Operators List 2, January 1973, and Statistics Canada 41-001, all BOF are in Ontario.

[3] Total Canadian Production in OH Furnaces minus Sysco production, EM&R, Operators List 2, January 1973, Mineral Bulletin MR 132, Canadian Minerals Yearbook 1973. Sysco 1972 production estimated at 800,000 tons.

[4] Remainder of production.

TABLE 3.10b

PER UNIT ENERGY REQUIREMENTS[9]
IRON AND STEEL

(Btu x 10^6/unit)[7]

Production Process (variable)	Energy Form			
	Fuel Oil	Natural Gas	Coal	Electricity
Blast Furnace:				
Fuel oil supp. (Qif)	1.5[1,6]	0.0	21.9[5]	0.05[1]
Nat. gas supp. (Qig)	0.0	2.3[1]	21.9[5]	0.05[1]
Open Hearth Furnace:				
Scrap charge (q_1)	0.45[1,2,3]	0.92[1,2,3]	0.0	0.07[2,8]
Pig iron charge (q_2)	0.60[1,2,3]	2.77[1,2,3]	0.0	0.07[2,8]
Basic Oxygen Furnace:				
Scrap charge (q_3)	0.0	0.0	0.0	0.12[1,2,8]
Pig iron charge (q_4)	0.0	0.0	0.0	0.12[1,2,8]
Electric Furnace:				
Scrap charge (q_5)	0.0	1.0[4]	0.0	1.88[1]
Pig iron charge (q_6)	0.0	1.0[4]	0.0	2.16[1,2]
Finishing (Qf)	0.13[1]	1.3[1]	0.0	0.75[1]

[1] Ontario Hydro report.

[2] Gordian Associates.

[3] Acres' estimate.

[4] Acres' survey.

[5] Coke rate and coal-coke conversion as discussed in text.

[6] Oil has lower combustion rate than gas.

[7] Units are tons.

[8] Oxygen production at 500 kwh/ton of oxygen.

[9] Calculations of pig iron charges are based on gross data and include allowance for production of pig iron for the Iron Foundry Industry. Iron foundry requirements are approximately 3.5% of total pig iron produced.

3.11 - Lime

3.11.1 - Industry Overview - Energy Use

In 1973 Ontario lime manufacturers consumed almost 6.0×10^{12} Btu of energy. While this consumption represented only 0.7 per cent of the total provincial industrial energy consumption, the fuel consumption of this industry per dollar of shipments is the highest in the industrial sector. Energy sources for this industry are coal, fuel oil, natural gas and electricity.

3.11.2 - Industry Overview - Markets

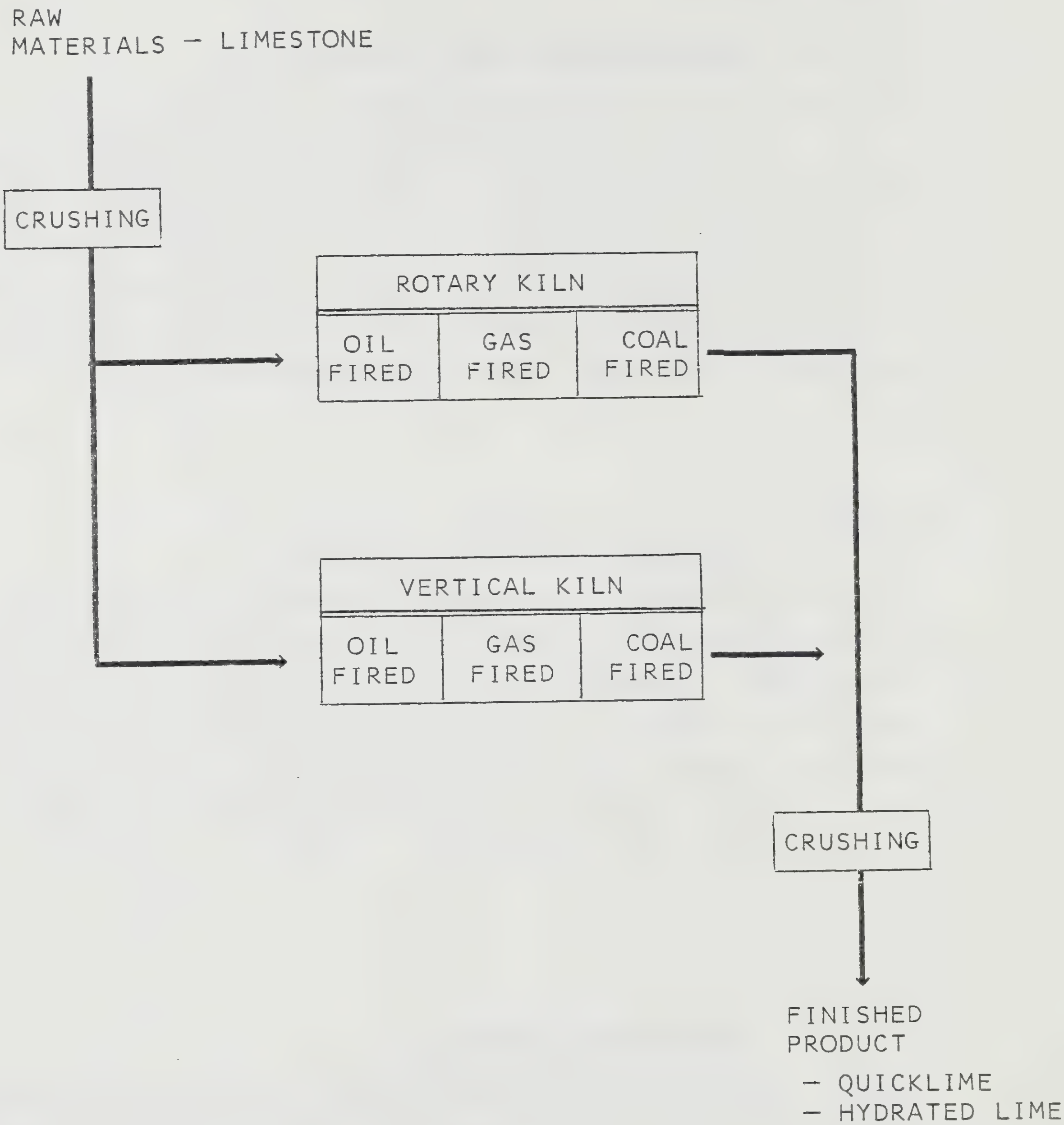
The lime industry is primarily domestic in nature and a large portion is used by the steel and pulp and paper industries. Imports of lime into Ontario have occurred only as a result of serious local equipment breakdown. There is some export into the northern United States. Future market trends will be tied directly to activity in the above two industries.

3.11.3 - Production Process

Lime, a caustic solid, white when pure, is obtained by calcining limestone or dolomite. The process is simple, consisting of burning or calcining limestone in a rotary or vertical kiln. The vertical kiln is also known as a shaft kiln.

Apart from the use of shaft kilns, not used by the cement industry, calcining of limestone is very similar to the production of cement clinker in a dry kiln. The major

PRODUCTION PROCESS
LIME



difference here is that there is no need for the raw grinding of limestone prior to calcining in the kiln.

Rotary Kilns

The rotary lime kiln is very similar to a cement kiln. Limestone, crushed to a size in the order of 1-3/4 inches by 1/2 inch is burned much like cement. Lime can absorb sulphur from the kiln fuel. If the final product specifications call for a low sulphur lime, then either a low sulphur fuel or a low sulphur limestone has to be used. Logically, it is the sulphur content of the limestone that controls the type of fuel that can be used.

Shaft Kilns

A shaft kiln is a vertical furnace much like a blast furnace in which reducing gases are fired from below and the limestone is fed from above. The size of limestone fed into this kiln is larger than for rotary kilns, being in the order of 4-1/2 inches by 2 inches. Use of smaller limestone is prevented mainly by draft considerations. Shaft kilns are normally more energy-efficient when compared to rotary kilns, however, sulphur pick-up in shaft kilns is greater than in rotary kilns.

3.11.4 - Energy Consumption

Energy represents more than 50 per cent of this industry's operating costs. Kiln fossil fuel consumption varies substantially in this industry. The present average is in the range of 4 to 5 million Btu per ton. Here kiln design is of major importance.

Although the fuel consumption per ton of product is somewhat higher in the rotary kiln, both in terms of fossil fuels and the need for motor drives, and there is generally higher capital investment required for a rotary, by far the greatest percentage of product is handled in this type of kiln. The advantages are: the utilization of all sizes of limestone; better control of feed and temperature; and greater production per man-hour due to a higher production rate per units than shaft kilns.[1]

3.11.5 - The Future Outlook

Technology

Presently there are on the market kilns with preheaters that can produce lime using only approximately 3.2 million Btu of fossil fuels per ton (a saving of some 25 per cent). No detailed information was available on these kilns. However, they are included here and in the model as a probable future technology. The costs of this new equipment are so high that the industry cannot arbitrarily install it. There are also conflicting views concerning sulphur pick-up by various kilns. Views of industry spokesmen vary substantially on this subject and obviously reflect their operating experience.

A gradual shift of the steel industry to greater use of the BOF process at the expense of the open hearth will retain the market domination of the rotary kilns. This is because the BOF process requires the low sulphur lime produced in rotary kilns.

Electrical needs of this industry, primarily for motor drives, are estimated at 30 kwh per ton when a rotary kiln is used in the heating process.

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[1] The Conference Board, Energy Consumption in Manufacturing.

Conservation

On the surface there appears to be a substantial potential for reducing unit energy consumption in this industry. A closer examination reveals, however, that the requirements for low sulphur lime in BOF steelmaking which is best produced in the relatively heavy energy-using rotary kiln will place some constraint on achievable energy conservation. Reliable information on future energy availability is also necessary before significant investment aimed at reducing energy use can be considered. Finally, the high cost of modernization is a valid deterrent. Thus a realistic examination of long-term energy use trends indicate that it is probable that unit energy efficiency will be improved by 10 per cent between 1973 and 1980 with present equipment and a further 10 per cent reduction by 1990 with some new investment.

3.11.6 - Industry Model

Lime industry processes are essentially the same as those of the cement industry: crushing and heating. As mentioned above, three types of kilns are possible in the heating component, vertical and rotary with and without preheaters. Any of the three fossil fuels can be used depending on the sulphur content of the raw materials. The processes, therefore, are ten:

- Crushing,
- Vertical kiln (coal, oil or gas-fired),
- Rotary kiln (coal, oil or gas-fired),
- Rotary kiln with preheater (coal, oil or gas-fired).

Total production of lime, in tons, was available on a provincial basis from Statistics Canada. No precise data was obtained, however, for the output by each of the two major processes for the vertical and rotary kilns. Discussions with the industry revealed that the appropriate split would be 10 per cent vertical and 90 per cent rotary. There appear to be no rotary kilns currently in operation that are equipped with preheaters. Current capacity was estimated only in approximate terms in these discussions as 140,000 tons per year for the vertical kiln and 1.25 million tons for the rotary kiln.

The major markets for lime are in the iron and steel, and the pulp and paper industries. Over 45 per cent of the total Canadian lime production went to these two industries in 1973.[1] The independent variables in the forecast are the total Ontario production of chemical wood pulp and the total Ontario production of steel ingots and castings, both expressed in tons (sections 3.10 and 3.14).

Total lime production is therefore forecast as:

$$(11.1) \ldots Q_t = 746{,}792 + 0.08\ (PULPC) + 0.02\ (STEEL)$$

Nine heating processes were identified (based on three fuels and three kiln designs) but no energy consumption information was obtained in the survey. Based on the literature and total consumption data, the proportion of output by process was estimated and the unit energy requirement computed. Vertical or shaft kilns are slightly more efficient because they handle much smaller capacities of limestone and the smaller surface area per unit of weight of the larger limestone feed to this of furnace.

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[1] Statistics Canada.

Data was not available that would indicate significant differences in per unit energy consumption by type of fuel, thus until better information is available, all three fossil fuels are assumed equally efficient. It was also necessary to postulate the type of fuel consumed by kiln type in the absence of an inventory of kilns. The current provincial distribution was used: natural gas (70%), fuel oil (17%) and coal (13%). Based on this data the following proportions of production are assumed (1976):

	Fuel Oil (%)	Natural Gas (%)	Coal (%)	Total (%)
Vertical	1.7(p_1)	7.0(p_2)	1.3(p_3)	10.0
Rotary	15.3(p_4)	63.0(p_5)	11.7(p_6)	90.0
Rotary (pre-heater)	0.0(p_7)	0.0(p_8)	0.0(p_9)	0.0
Total	17.0	70.0	13.0	100.0

Thus,

(11.2) ... $q_1 = p_1 Q_t$
= tons of lime from vertical oil-fired kilns.

(11.3) ... $q_2 = p_2 Q_t$
= tons of lime from vertical gas-fired kilns.

(11.4) ... $q_3 = p_3 Q_t$
= tons of lime from vertical coal-fired kilns

(11.5) ... $q_4 = p_4 Q_t$
= tons of lime from rotary oil-fired kilns.

(11.6) ... $q_5 = p_5 Q_t$
= tons of lime from rotary gas-fired kilns.

(11.7) ... $q_6 = p_6 \, Q_t$
$=$ tons of lime from rotary coal-fired kilns.

(11.8) ... $q_7 = p_7 \, Q_t$
$=$ tons of lime from rotary oil-fired kilns with preheater.

(11.9) ... $q_8 = p_8 \, Q_t$
$=$ tons of lime from rotary gas-fired kilns with preheater.

(11.10)... $q_9 = p_9 \, Q_t$
$=$ tons of lime from rotary coal-fired kilns with preheater.

The per unit energy requirement for fossil fuels in the rotary kiln with preheater is set at the estimate of 3.2 million Btu discussed in section 3.11.4. The same electrical requirement for kilns with and without preheaters was used.

TABLE 3.11a

VARIABLES IN OUTPUT FORECASTING EQUATION

Year	Dependent Variable	Independent Variables	
(t)	(Q_t)	(PULPC)	(STEEL)
1964	1,049,798	1,729,292	7,581,251
1965	1,132,193	1,787,607	8,485,219
1966	1,078,350	2,042,818	8,453,480
1967	974,458	2,184,629	8,333,431
1968	1,013,712	2,161,606	9,400,741
1969	1,129,274	2,260,131	7,960,199
1970	1,164,591	2,327,554	10,129,433
1971	1,167,053	2,318,150	10,010,166
1972	1,205,793	2,640,219	10,768,167
1973	1,236,382	2,645,824	12,040,019

where, Q_t is total Ontario output of lime in tons, Source: Statistics Canada 26-201

PULPC is total tons of wood pulp produced in the chemical (sulphite and sulphate) processes. Estimated in section 3.14

STEEL is total tons of steel ingots and castings produced in Ontario, section 3.10 and Statistics Canada 41-203.

TABLE 3.11b

PER UNIT ENERGY REQUIREMENTS
LIME

(Btu x 10 /unit)[1]

Production Process (variable)	Energy Form: Fuel Oil	Natural Gas	Coal	Electricity
Crushing (Q_t)	-	-	-	.07
Vertical Kiln:				
oil-fired (q_1)	4.36	-	-	-
gas-fired (q_2)	-	4.36	-	-
coal-fired (q_3)	-	-	4.36	-
Rotary Kiln:				
oil-fired (q_4)	4.74	-	-	.04
gas-fired (q_5)	-	4.74	-	.04
coal-fired (q_6)	-	-	4.74	.04
Rotary Kiln with Preheater:				
oil-fired (q_7)	3.2	-	-	.04
gas-fired (q_8)	-	3.2	-	.04
coal-fired (q_9)	-	-	3.2	.04

Source: Acres' estimates.

[1] Units are tons.

3.12 - Mining, Milling, Smelting and Refining

3.12.1 - Industry Overview - Energy Use

This classification includes firms producing a list of basic commodities ranging from lead to gold. Most operations include more than one product with the result that little data is available for individual commodities. The production of this sector is concentrated, in terms of the value of production, in three products: nickel, copper and zinc. These three accounted for some 68 per cent of the production value from the industry in 1973.[1] Energy consumption in this sector in 1973 was 66.8 x 10^{12} Btu, which represents 8.1 per cent of the total industrial energy usage in that year. The mining segment of this classification consumed 32.4 x 10^{12} Btu of the energy while the smelting and refining segment consumed the remaining 34.4 x 10^{12} Btu. The energy forms are summarized below:

	Mining & Milling	Smelting & Refining
	(%)	(%)
Coal	2.0	27.4
Fuel oil[2]	20.4	8.1
Natural gas	37.8	47.5
Electricity	36.7	16.9
Other[3]	3.1	0.1
	100.0	100.0

[1] Nickel \$574 million (33.6%); Copper \$365 million (21.4%); Zinc \$220 million (12.7%).

[2] Diesel oil, kerosene, light fuel oil and heavy fuel oil.

[3] Includes gasoline.

3.12.2 - Production Process

The treatment of the crude rock to produce a refined consumer product is divided roughly into four operations: mining, milling, smelting and refining. Each of the four is in itself the combination of a variety of processes. The process mix is defined by the type of mine, the concentration of the desired product at the mine, the transport costs from processing site to processing site, the number of products/by-products to be produced and a myriad of other factors.

Mining involves the removal of the ore from the ground and its transportation to the surface and the mill gate. Electricity is used for light, and much of the underground motive power as well as ventilation. Other energy forms used are gasoline and diesel fuel for surface and some underground transportation and fuel oil and natural gas for heat, boiler fuel and electrical generation.

The remaining steps of the production process are described in terms of the three primary outputs of the industry: nickel, copper and zinc. The milling operation is essentially a mechanical, physical and surface chemical operation.

In the milling operation the ore is crushed then ground into a fine powder and the copper, nickel and zinc concentrate is separated by the flotation process. Electricity is the primary energy form in the operation being used for both crushing and pumping. Fossil fuels are consumed for heat and for electric generation. The concentrate derived from this operation is shipped to the smelter for further processing. The copper concentrate is 20 to 30 per cent Cu, the nickel is 10 to 20 Ni and

the zinc is 50 per cent Zn. The moisture content is in the order of 6 to 8 per cent.

The remaining two operations, smelting and refining, involve basic physical and chemical changes in the input materials. Smelting generally consists of three steps; roasting, smelting, and converting. Each will be dealt with separately.

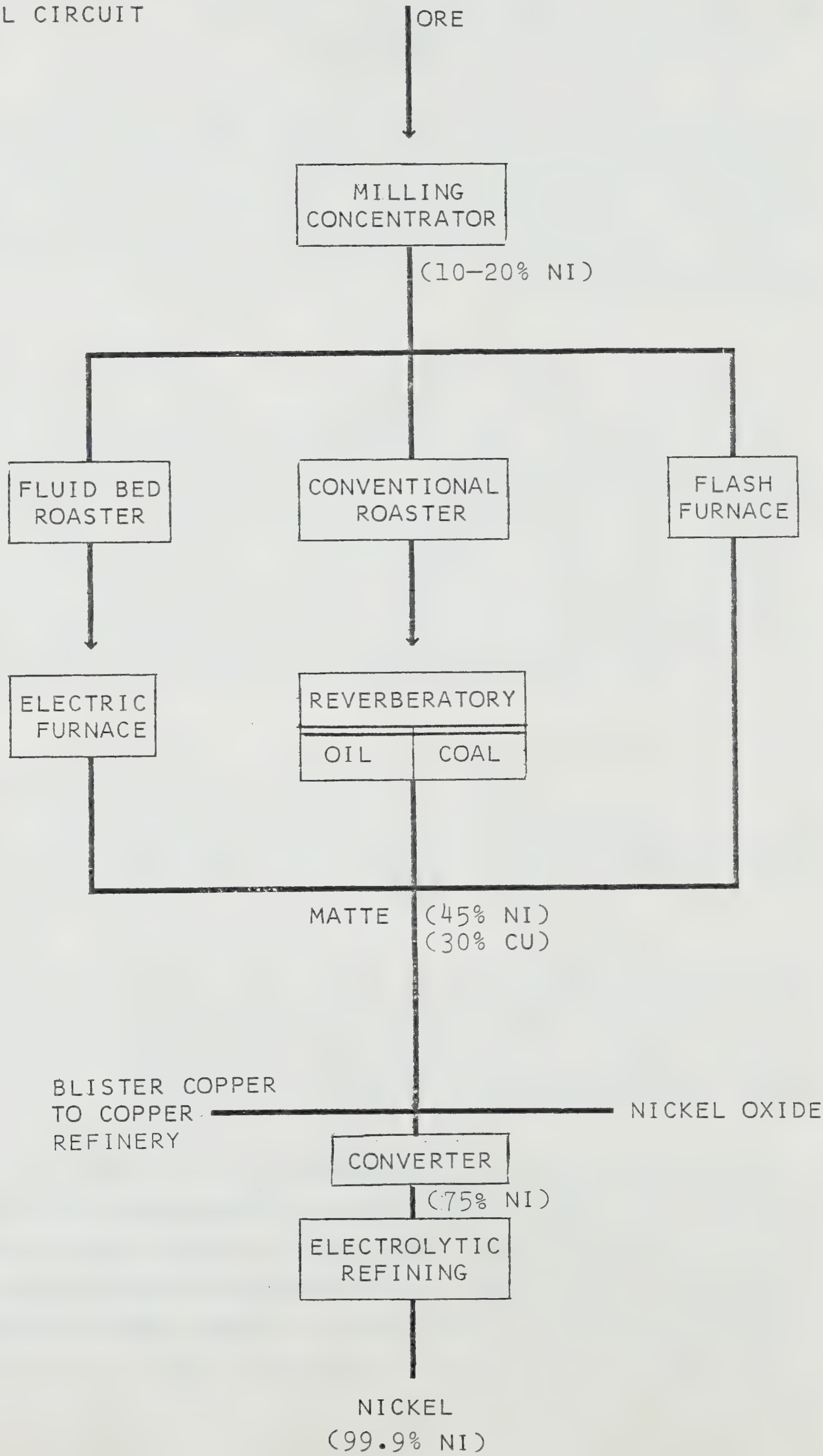
Two types of roasting furnace are in common use. The multi-hearth roaster consists of a series of superimposed circular hearths. The concentrate is introduced at the top hearth and raked slowly from there to the lower hearths. As the concentrate passes downward, it is gradually heated by the rising hot gas from the roasting that is taking place below. Finally the iron sulphides in the feed reach their ignition temperature and start to burn. The roasting process is exothermic requiring no external fuel sources.

The fluid bed roaster is a vertical chamber into which the concentrate and an oxygen bearing gas, usually air, are blown. As the concentrate is fed to the furnace the air is injected at a sufficient velocity to hold the particles in suspension. Since each sulphide particle is in constant turbulent motion in the furnace atmosphere, roasting is uniform and rapid, with efficient heat transfer and high oxygen utilization.

The roasting phase of the production process is to oxidize the iron in the ore and retain the copper/nickel values as a sulphide. The output of the roaster is called calcine. Smelting is a thermal treatment of the ore concentrates to melt them to bring about changes that enable recovery of the metals. The aim is to

PRODUCTION PROCESS
MINING, MILLING, SMELTING & REFINING

NICKEL CIRCUIT



segregate the wanted constituents in a matte and reject the unwanted in a slag. Three types of furnace are commonly used in this phase: reverberatory, electric and flash.

In the reverberatory furnace, fossil fuel -- pulverized coal or fuel oil -- is burned separately from the material being smelted. Fuel oil is preferred to natural gas because of greater flame luminosity and better heat transfer. The calcine from the roasters is fed to the furnace through pipes in the furnace roof. As the calcine melts the matte settles and slag flows toward the tapping end of the furnace, opposite the burners, where it is removed.

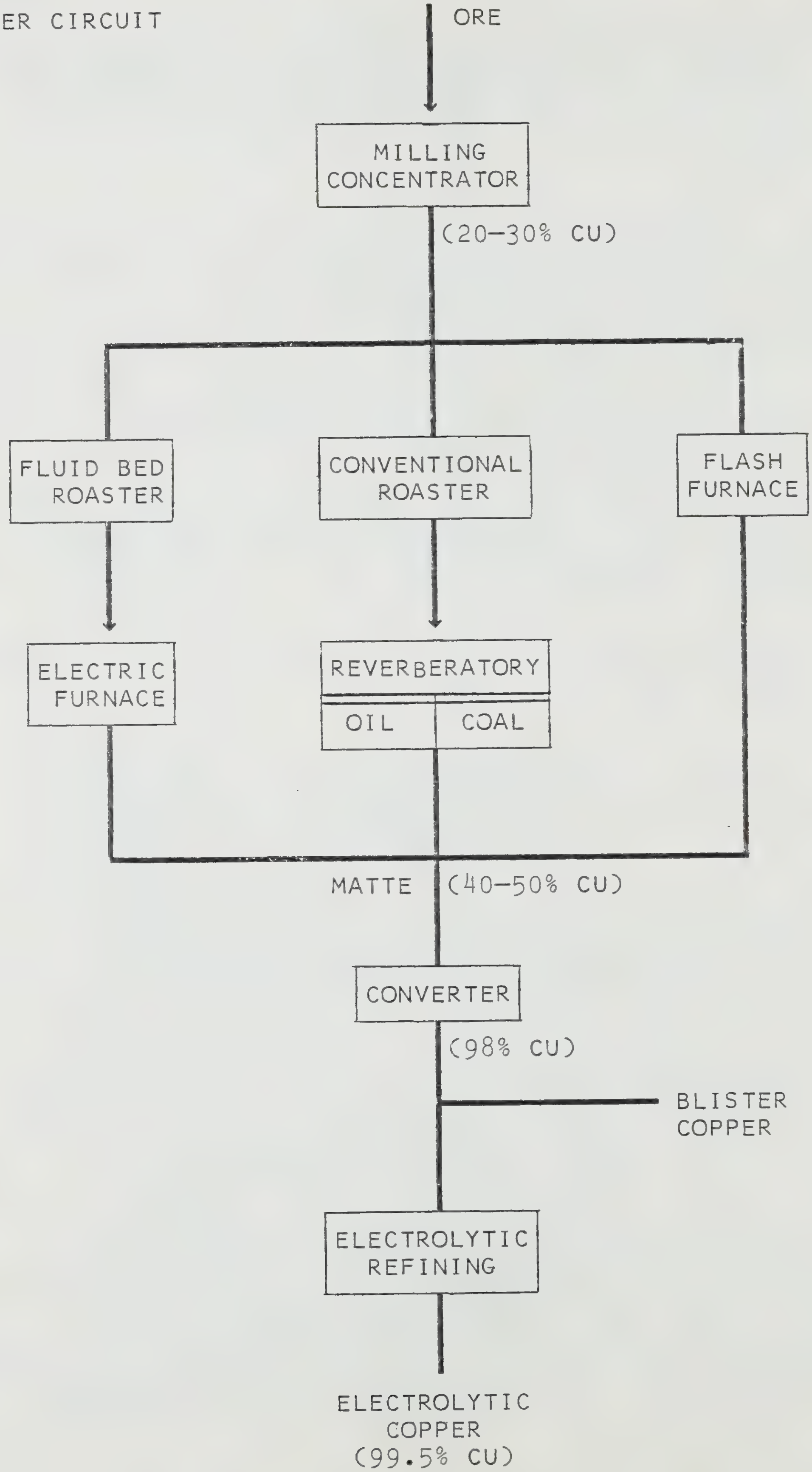
The matte is tapped from a second port in the furnace and sent to the converter.

When employed in the smelting operation the electric furnace is operated on the "submerged arc" principle. Electrodes in contact with the slag layer of the bath form a circuit with the slag. The heat generated by the slag's resistence to the current produces the smelting temperatures. The calcine from the roaster is fed through the roof of the furnace forming a layer over the already molten slag. As the new feed melts it separates into the slag and matte layers. The slag and matte are tapped intermittently as required.

In the flash furnace a sulphide ore concentrate is flash smelted by burning some of its sulphur and iron content while the concentrate is suspended in the oxidizing medium, in much the same manner as pulverized coal is burned. The concentrate and a flux material

PRODUCTION PROCESS
MINING, MILLING, SMELTING AND REFINING
AND REFINING

COPPER CIRCUIT



are injected, with commercial oxygen or preheated air, into a furnace. The smelting temperature is obtained by the "flash" combustion of the iron and sulphur. The concentrate is made to roast and smelt itself in a single strongly exothermic reaction.

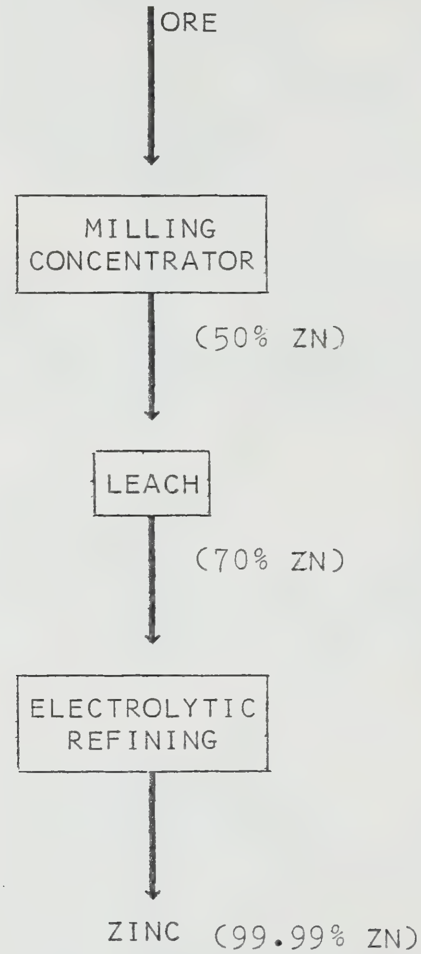
The output from each of the three smelting operations is the same. The nickel circuit produces a matte which is 45 per cent nickel and 30 per cent copper, the copper circuit produces a matte which is 40 to 50 per cent copper.

Fluid bed roasters are used in conjunction with electric furnaces, and the multi-hearth roaster is usually used in conjunction with a reverberatory furnace. The flash furnace is used alone.

Nickel, copper, precious metals and most of the sulphur that was combined with them remain in the matte. The converting procedure is to blow air through the molten matte, the air's oxygen combining with the iron and sulphur to form iron oxides and sulphur dioxides. The sulphur dioxide passes off as a gas, and the iron oxide unites with added silica flux to form iron silicate slag. The oxidation takes place in the molten matte in a highly exothermic reaction that liberates enough heat to maintain molten conditions. The result of the operation is 98 per cent pure copper or 75 per cent nickel depending on the circuit. Before the 75 per cent level of nickel concentration is achieved the copper-nickel matte from the nickel circuit is cooled, crushed and subjected to another flotation and roast operation to separate the two metals. The separated copper is transferred to the copper circuit while the nickel goes to the refining stage of the nickel circuit.

PRODUCTION PROCESS
MINING, MILLING, SMELTING AND REFINING

ZINC CIRCUIT



In the final process the matte is melted in a reverberatory furnace and cast into anodes. These are placed in an electrolytic solution and a current is passed between it and a refined starting cathode. As the current flows through the cell, the metal from the anode dissolves in the adjacent electrolyte -- the anolyte. This solution is pumped from the cell, impurities removed chemically, and the purified electrolyte is returned to the cell as catholyte -- the electrolyte adjacent to the cathode. The dissolved metal from the catholyte is then deposited on the cathode. The result is a cathode which is either 99.9 per cent pure nickel or 99.5 per cent pure copper depending on the circuit.

The zinc circuit involves four steps: milling, roasting, leaching and electrolytic refining. All but the leaching process are the same as in the copper or the nickel circuits. In the leaching process the zinc calcine is dissolved in a hot acid (100°C) to remove the zinc oxides and ferrites. The slurry produced is then purified and pumped into the electrolytic cells where the zinc is plated out. The energy form required for this circuit is electricity for pumping and for electrolysis. Natural gas and other fossil fuels are used in the leaching process to heat both the ore and the liquid. In addition to their use in the smelting phase of zinc production, leaching tanks are often used as concentrators in the milling operation.

3.12.3 - The Future Outlook

Markets and Resources

The long-term outlook for basic mineral raw materials from Ontario depends on world-wide economic conditions, the resources available in the province and competing resources available elsewhere. All that can be sensibly said is that if the resources exist and can be processed at competitive prices, the mining industry will continue as a major factor in Ontario industry. To foresee levels of production, future discoveries, and new technologies that affect these developments, however, is virtually impossible. Basically, the long-term will be assumed to be a continuation of past trends, limited by resource constraints where they are obvious.

Technology

Few energy-related technological changes can be found in this sector. The major observed change involves the phasing out of the blast furnace and the related sintering operations in the nickel industry. Blast furnaces were used to smelt directly the high grade ore found in the Sudbury region. As this ore is depleted there is less need for the blast furnaces. In order to maintain a high throughput, the concentrate from the lower grade ore mines was charged to the furnaces. The blast furnace, however, cannot accept the fine powder from the normal milling operations of this ore. Therefore, it was necessary to agglomerate the powder into larger chunks using a sintering machine. As the blast furnaces are phased out they are being replaced by the reverberatory, electric and flash furnaces, thus reducing coal/coke usage and increasing electricity inputs.

A new process for the continuous smelting and converting of copper concentrates has been developed by Noranda Mines Limited. A pilot plant was constructed in 1968 with a design capacity of 100 tons of concentrates per day, and within five years, enough data had been collected to design, build and start up a commercial size unit capable of treating up to 1,600 tons of concentrate per day, when oxygen-enriched air is used.

The Noranda process has a number of advantages over the conventional method of smelting copper concentrate (the use of a reverberatory furnace and converters). One of the major advantages is a substantial reduction in the total energy required to produce copper and especially in the requirements of fossil fuels. This is due mainly to the fact that the heat produced during the oxidation of sulphides is used within the same vessel to help smelt the concentrates, unlike the conventional smelter where separate vessels are used for the oxidation and smelting stages.

The Noranda process requires nearly 700 kwh per ton of anode copper of additional purchased electrical energy because of the need for an oxygen plant and a slag converter. However, the fossil fuel requirements per ton of anode copper drop from approximately 19×10^6 Btu per ton to the 4×10^6 Btu level.

No smelters using the Noranda process are currently operating in Ontario.

The current 1975 grade of ore being mined by the largest producer of nickel and copper -- Inco -- averages 1.40 per cent nickel and 0.92 per cent copper. This compares

to 1.39 per cent and 0.97 per cent for nickel and copper respectively in 1974.[1] Ontario's largest producer of zinc -- Ecstall Mining Ltd. -- reported an average ore grade of 9.78 per cent zinc in 1973, compared to 10.14 the previous year.[2]

Reserves of nickel/copper bearing ores in Canada are estimated at 415 million short tons of grade 1.61 per cent nickel and 1.04 copper. These are the proven reserves for Inco alone. Current ore consumption for the company is in the order of 21 million tons per year. At the end of 1973 Ecstall reported ore reserves of 75 million tons grading 4.6 per cent zinc and 21 million tons grading 9.6 per cent zinc. Current company consumption (1973) is 3.6 million tons annually.

Other reserves of equal or better ore grade are known to exist in Ontario.[2]

Conservation

As in most other industries, the emphasis for energy conservation has been in the area of housekeeping measures and the recovery of waste heat. Potential also exists in this industry for on-site generation of electricity as there is a demand in the processes for both vast quantities of electricity and process heat. Unfortunately, this demand for heat in general is not in the form of steam. This fact may well limit the potential for on-site generation. Statistics Canada reported figures for on-site electrical generation in the mineral industries until

[1] The International Nickel Company of Canada, 1975 Annual Report.

[2] EM&R, Canada (Minerals Division), Canadian Minerals Yearbook, 1973.

1972. In that year only 0.05 per cent of total electricity demand in the mining operations of these industries in Ontario was generated on-site. The smelting and refining operations are listed as generating no electricity.

The survey indicated that there is little possibility for fuel substitution in this industry at the smelting and refining stage. Substitution was only suggested in the generation of steam. No indication of substitution between fossil fuels was obtained at the mining stage.

3.12.4 - Industry Model

For purposes of this study, energy consumption has been associated with the three metals accounting for most of the value of production: nickel, copper and zinc. The processes identified in this industry are:

- Mining of ore,
- Milling of ore,
- Electric furnace smelting of nickel and copper,
- Reverberatory furnace smelting of nickel and copper,
- Flash furnace smelting of nickel and copper,
- Leaching of zinc,
- Electrolytic refining of nickel,
- Electrolytic refining of copper,
- Electrolytic refining of zinc,
- Other operations.

As was mentioned earlier, the energy consumption data used in this sector from Statistics Canada is based on

consumption in two sectors: mining and smelting and refining. That consumed in the milling process is split arbitrarily between the two sectors. Thus, if an establishment is primarily engaged in the extraction of ores and does some milling in the process, the energy for all processes in the establishment would all be in the mining. If the establishment were primarily engaged in smelting, the energy expended in the milling process would be assigned to the smelting and refining sector. For this reason the total energy consumption figures derived for the mining sector of this model will not necessarily match those in Statistics Canada's review of the mineral industries.

Provincial output of various mineral products is readily available from Statistics Canada. Data does not, however, exist for the various phases of production, i.e. ore, concentrate, matte, finished product, nor are the methods of production listed.

For the purposes of this study, we have concentrated on the three major mineral products produced in the province: nickel, copper and zinc. These three account for 68 per cent of the value of production in this industry.

The output data of each is related to the general economic activity in the major export market, namely the United States, as expressed by the American Gross National Product in millions of constant 1958 dollars:

(12.1) ... $Qn = 0.265\ (USGNP)$

(12.2) ... $Qc = -27{,}777 + 0.41\ (USGNP)$

(12.3) ... $Qz = -388{,}378 + 1.01\ (USGNP)$

These total output figures represent the metal content in shipments of both refined and unrefined products. The refined portion is isolated by using a figure reflecting the historical proportion of refined to total production:

(12.4) ... qn = yn Qn - output of refined nickel (99.9%)

(12.5) ... qc = yc Qc - output of refined copper (99.5%)

(12.6) ... qz = yz Qz - output of refined zinc (99.99%)
where the historical national values of yn, yc and yz are:

Year	Nickel (yn)	Copper (yc)	Zinc (yz)
1964	0.592	0.838	0.493
1965	0.556	0.855	0.436
1966	0.432	0.856	0.397
1967	0.553	0.815	0.365
1968	0.523	0.828	0.368
1969	0.545	0.784	0.386
1970	0.539	0.808	0.364
1971	0.455	0.730	0.329
1972	0.506	0.689	0.422
1973	0.557	0.610	0.431

Source: Canadian Minerals Yearbook, 1973.

The figures for copper have decreased sharply over the 10-year period due to an increased demand for copper ore and matte in the export market. Thus, while the production and export of refined copper has leveled off in the past three years (1971-1973), the ratio of refined to total production has dropped.

The difference between the total output and the refined output is the total shipments of each metal in the matte form. For purposes of this model, all shipments which

are not in refined form are assumed to be in matte. For example, if total output, as specified in equation (12.1), (12.2) or (12.3) was 100,000 tons and the ratio of refined to total production (y_x) was 0.60, total shipments of refined metal (at say 99.9%) would be 60,000 tons and the remainder of 40,000 tons would represent shipments of recovered metal in matte. If matte contained 45 per cent metal, the total tons of matte required to supply the 100,000 tons of metal is computed as (.999/.45) x 100,000 = 222,000 tons.

A summary table of the concentration of metal to total output by weight at each stage of production is as follows:[1]

	Ore	Concentrate	Matte	Refined
	(%)	(%)	(%)	(%)
Nickel	1.4[2] (p_1)	10-20 (p_2)	45 (p_3)	99.9 (p_4)
Copper	0.92[2] (p_5)	20-30 (p_6)	40-50 (p_7)	99.5 (p_8)
			Leach	
Zinc	9.8 (p_9)	50 (p_{10})	70 (p_{11})	99.99 (p_{12})

Total output of matte for each metal is therefore:

(12.7) ... $Qnm = (p_4/p_3) \times Qn$

$= \text{tons of matte containing nickel.}$

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1 Boldt, The Winning of Nickel,
Taggert, Handbook of Mineral Dressing, Ores and Industrial Minerals,
EM&R, Canadian Minerals Yearbook, 1973.

2 Inco averages.

3 Ecstall Mining Ltd. average.

(12.8) ... $Qcm = (p_8/p_7) \times Qc$
$= \text{tons of matte containing copper.}$

Total output of concentrate for nickel and copper is based upon the ratio of the percentage concentration of metal in the matte to that in the concentrate. As no zinc matte is produced, zinc concentrate is computed from the relationship of total production to refined production:

(12.9) ... $Qnc = (p_3/p_2) \times Qnm$
$= \text{tons of concentrate containing nickel}$

(12.10)... $Qcc = (p_7/p_6) \times Qcm$
$= \text{tons of concentrate containing copper}$

(12.11)... $Qzc = (p_{12}/p_{10}) \times Qz$
$= \text{tons of concentrate containing zinc.}$

There are three basic types of furnaces used in the smelting of nickel and copper. The total production of nickel and copper concentrate has been apportioned among the furnaces based upon available data as to the capacities of each type in the province. These capacities were estimated from Boldt, The Winning of Nickel and Statistics Canada in terms of the tons of concentrate input per year.[1]

	Electric	Reverberatory	Flash
Nickel	730,000 ($pn_1 = 16.1\%$)	3,800,000 ($pn_2 = 83.9\%$)	0 ($pn_3 = 0.0\%$)
Copper	600,000 ($pc_1 = 11.7\%$)	4,000,000 ($pc_2 = 77.7\%$)	550,000 ($pc_3 = 10.6\%$)

---

[1] Assuming that all operations are running at the same proportion of capacity and that Falconbridge has replaced its blast furnace with equal electric capacity.

Production by furnace type is assigned based upon these proportions and the total input of concentrate as follows:

(12.12) ... $q_1 = pn_1\ Qnc + pc_1\ Qcc$
= tons of concentrate charged to electric furnaces

(12.13) ... $q_2 = pn_2\ Qnc + pc_2\ Qcc$
= tons of concentrate charged to reverberatory furnaces

(12.14) ... $q_3 = pn_3\ Qnc + pc_3\ Qcc$
= tons of concentrate charged to flash furnaces

The output of the mining process is based on the assumption that the ore required to satisfy nickel and zinc production will serve as a proxy for total ore mined for all minerals. (Nickel and copper are extracted from the same mine output). The ore requirement is computed from the ratios of metal contained in the concentrate to ore grade for the two metals.

(12.15) ... $Qm = ((p_2/p_1) \times Qnc) + ((p_{10}/p_9) \times Qzc)$
= tons of ore mined for nickel and zinc.

This figure is also used as the measure of production of the milling process.

Other operations in the sector are deemed to be reflected in the total tons of ore mined as computed above. This would include the processing of all other products of the sector. The mining of these other products is assumed to be included in the mining process.

A major component of these two general processes is the mining and pelletizing of iron ore. This process was not included explicitly as there was insufficient process information to do so. The following facts were available.[1] Approximately 1.25 to 1.35 tons of iron ore pellets are required to produce one ton of pig iron in a blast furnace. Approximately 80 per cent of the Canadian blast furnace iron ore feed is in the form of pellets. Pellets contain 66 to 67 per cent iron. Ontario iron ore production consisted of 73 per cent pellets, 18 per cent sinter, 8 per cent concentrate and 1 per cent direct ore. Approximately 60 per cent of this production was consumed within the province, the remainder was exported. Iron ore from other provinces was shipped to Ontario to satisfy total provincial demand in the steel industry.

Energy requirements for the mining and processing of iron ore (pelletizing, production of sinter, etc.) consumed 1 million Btu per ton of contained iron. This is a Canada-wide average and comprises 0.07 per cent coal, 16.9 per cent natural gas, 60.7 per cent fuel oil and 22.4 per cent electricity.[2]

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[1] EM&R, Canada (Minerals Division), Canadian Minerals Yearbook, 1973.

[2] Statistics Canada, General Review of the Mineral Industries, 26-201, 1973.

In summary, the units used to measure the output by process and the associated variables are:

Process	Output (tons)	Ni	Cu	Zn	Total
Mining	Ore	-	-	-	Qm
Milling	Ore	-	-	-	Qm
Smelting	Concentrate	Qnc[1]	Qcc[1]	-	-
Leaching	Refined product	-	-	qz	-
Refining	Refined product	qn	qc	qz	-
Other	Ore	-	-	-	Qm

The per unit energy requirements were based on the survey and the literature. Data for mining were derived from total Statistics Canada data for the sector divided by the computed output measure. This overestimates energy consumption as it includes energy for many milling operations. The figures for other operations were computed as that data required to balance the model to total energy consumption in 1973.

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[1] Distributed by furnace type: tons of concentrate charged to electric furnaces in q_1, reverberatory furnaces in q_2 and flash furnaces is q_3.

TABLE 3.12a

VARIABLES IN OUTPUT FORECASTING EQUATION

Year	Dependent Variables			Independent Variable
(t)	(Qn)	(Qc)	(Qz)	(USGNP)
1964	162,094	197,917	72,076	580,000
1965	191,283	216,272	60,675	617,800
1966	160,214	202,976	82,395	647,800
1967	190,059	276,146	268,532	675,200
1968	203,747	290,618	346,758	707,200
1969	146,781	238,810	360,286	725,600
1970	224,255	295,092	340,242	722,500
1971	216,753	302,370	365,725	746,300
1972	189,428	289,723	403,391	792,500
1973	196,647	287,323	456,365	839,200

where, Qn is total provincial output of nickel in tons, includes refined nickel, nickel in matte, oxides and salts and recoverable nickel in concentrates (Statistics Canada 26-201),

Qc is total provincial output of copper in tons, includes copper in matte, refined copper and contents of blister copper (Statistics Canada 26-201),

Qz is total provincial output of zinc in tons, includes refined zinc and recoverable zinc in ores (Statistics Canada 26-201),

USGNP is United States Gross National Product in millions of constant 1958 dollars.

TABLE 3.12b

PER UNIT ENERGY REQUIREMENTS
MINING, MILLING, SMELTING AND REFINING

(Btu x 10^6/unit)[1]

Production Process (variable)	Energy Form			
	Fuel Oil	Natural Gas	Coal	Electricity
Mining (Qm)	0.12[5]	0.71[5]	-	0.49[5]
Milling (Qm)	-	-	-	0.2[2,3]
Smelting:				
electric (q_1)	-	-	-	1.4[2]
reverberatory (q_2)	3.5[2]	-	3.5[2]	-
flash (q_3)	-	-	-	0.4[2,4]
Leaching (qz)	-	-	-	0.5[2]
Refining:				
nickel (qn)	-	-	-	1.4[2]
copper (qc)	-	-	-	1.4[2]
zinc (qz)	-	-	-	11.9[2]
Other operations (Qm)	0.02[5]	0.94[5]	0.18[5]	0.014[5]

[1] Units are tons as discussed in text.

[2] Acres' survey.

[3] 45 kwh/ton of ore.

[4] .25 ton of oxygen per ton of concentrate.

[5] Balance to 1973 Statistics Canada energy data.

3.13 - Petroleum Refining

3.13.1 - Industry Overview - Energy Use

During 1973 Ontario refineries processed 150 million barrels of crude oil.[1] In that year the industry consumed 6.8×10^{12} Btu of purchased energy. This represents less than one per cent of the total industrial purchased energy consumption. In addition to this energy, however, the industry consumed 60.7×10^{12} Btu of its own end products. Statistics Canada data (45-004) reveals that 7.2 per cent of the Btu content of the crude oil throughput was utilized for processing.

Purchased fuel data indicates that half of the fuel is natural gas and the other half is electricity.

3.13.2 - Industry Overview - Capacity and Markets

Ontario's seven operating refineries had in 1975 a combined capacity of 540,300 barrels per calendar day (bpcd).[2] The imminent completion of two new refineries will add 265,000 bpcd to the above figure. Industry sources believe that no major additions to refining capacity will be required for the next 10 years. This capacity is summarized below.[2]

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[1] 1975 figure is 162 million barrels, Statistics Canada 45-004.

[2] EM&R, Canada (Mineral Development Sector), Operator's List 5.

All flow rates are barrels per calendar day unless otherwise stated.

Refinery - Location	Crude Oil Capacity (bbl/day)
BP - Oakville	76,000
Gulf - Clarkson	79,100
Imperial - Sarnia	127,700
Texaco - Port Credit	48,000
Shell - Oakville	44,000
Shell - Corunna	80,000
Sun Oil - Sarnia	85,500
Total - existing	540,300
Texaco - Nanticoke (1978)	95,000
Petrosar - Sarnia (1977)	170,000
Total - planned	265,000
TOTAL	805,300

The substantial refinery capacity that exists in Quebec and the Maritimes will also decrease any possibility of further Ontario refinery expansions within the next decade. A major unknown is the future growth rate in demand for petroleum products. The effect of government oil pricing policies on demand growth cannot be accurately assessed at this time.

In general, the market area for Ontario refineries is within provincial boundaries (excluding Ottawa Valley). There are in-flows and out-flows of product depending on the season and local demand factors but basically activity is tied to the provincial economy.

3.13.3 - Production Process

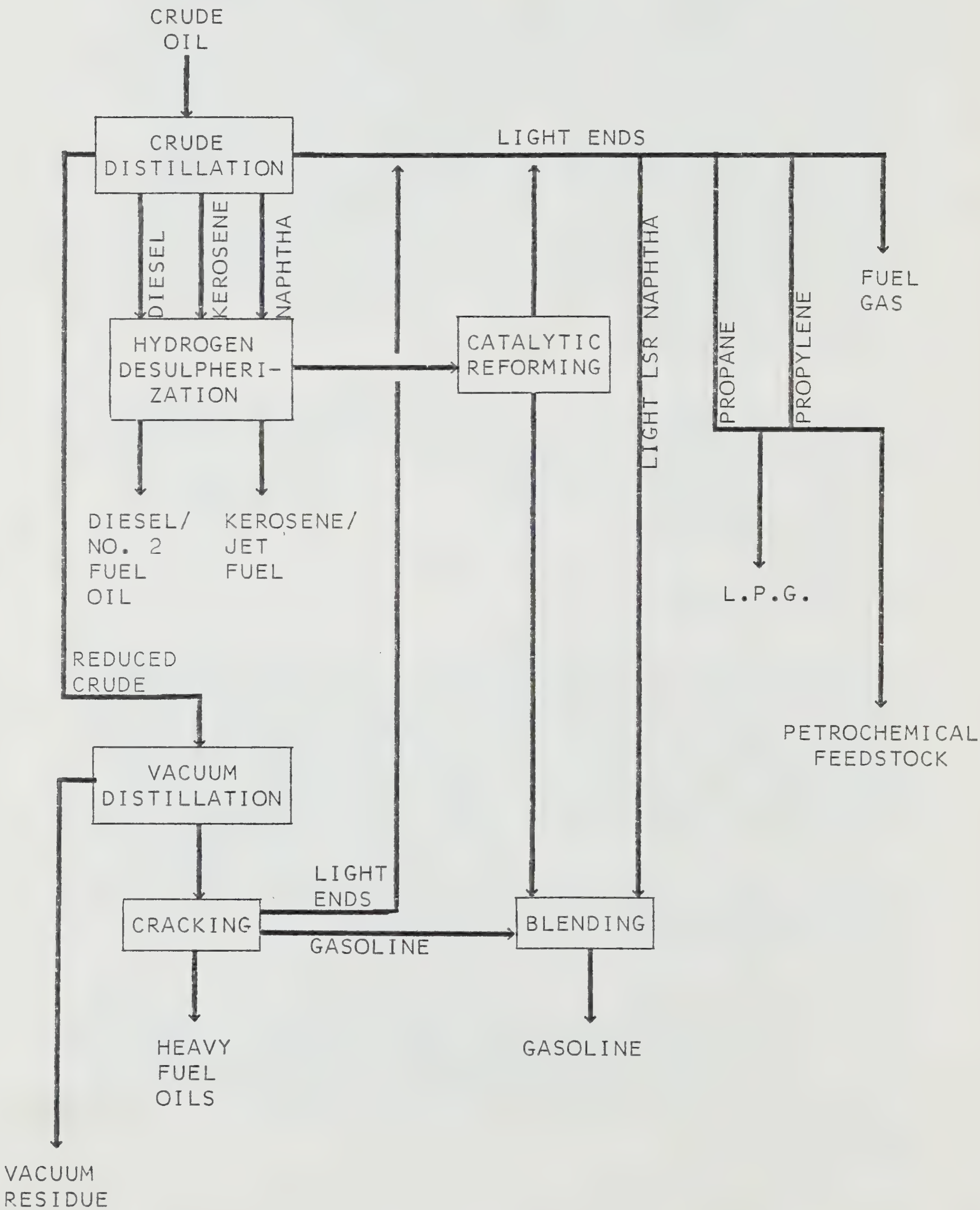
An oil refinery is both a complex distillation and a chemical conversion facility in which petroleum molecules are modified and recombined. In the distillation process the crude oil is heated so that various fractions are progressively evaporated. The resulting vapours, drawn off and condensed, form the lighter petroleum fractions such as gasoline, kerosene and heating oil. Heavier fractions for lubricating oil and residual fuel oils are also evaporated under vacuum conditions, leaving only pitch.

To increase the yield of gasoline blending components heavier fractions may be converted by means of either a thermal or catalytic process. In these processes, heavier components of crude oil are subjected to high temperatures and pressures which split and recombine the hydrocarbon molecules.

Processes such as hydrogenation, reforming, polymerization, and alkylation modify the chemical structure of the petroleum molecules producing gasoline and other substances which have not only the desired physical properties (notably boiling point for gasoline and viscosity for heating oil), but also desirable chemical properties (notably high anti-knock rating and lack of gum forming tendencies for all fuels).

Of some 2,000 individual products produced by refineries, about 1,500 are in the lubricants category, including oils and greases. Only two Ontario refineries have lube plants.

PRODUCTION PROCESS
PETROLEUM REFINING



In the final analysis, product requirements and crude oil characteristics determine the actual chain of processes employed by a refinery at a given point in time.

3.13.4 - Energy Consumption

Total energy consumption in this industry is closely related to a refinery's operating levels. A refinery that operates close to its design capacity requires less energy per unit of output than one operating at 70 per cent of capacity. Reducing the operating ratio from 90 to 70 per cent can, according to industry sources, increase a refinery's process energy requirements by some 2 per cent of throughput. In this regard the fixed fuel load, that fuel consumed regardless of throughput, becomes a significant factor when the throughput is reduced. Imperial Oil estimates that when their refinery is running at 72 per cent of capacity, the fixed load comprises 37 per cent of all energy consumed. If the plant were run at 100 per cent capacity, the fixed load drops to 30 per cent of energy consumed.

The quality of the crude oil to be refined does affect process energy use as does the product mix of the refinery. Since the product mix can and does change from season to season and no two refineries operate exactly the same, only average energy consumption can be used for purposes of this study.

Unit process energy use in the industry can be reduced by greater use of heat recovery methods. Based on present technology, the practical limit to refinery process energy use for the industry is in the order of 6 per cent of crude oil throughput.[1] The attainment of these reduced process energy requirements would require not only optimum use of technology and heat recovery, but the continuous operation at high levels of capacity. In other words, the realization of low process energy use is not simply a matter of technology but a combination of technology and marketing. Low market demand can easily wipe out any gains made through improvements in technology.

3.13.5 - The Future Outlook

Markets

The demand for petroleum products from Ontario refineries will be largely determined within Ontario. Overcapacity may encourage some exports outside of Ontario but this will be largely a temporary phenomenon and the refinery capacity will not be geared to permanent export markets. The splits of refinery runs between the various types of fuels may change over time but no attempt has been made to project these changes.

In any event, the addition of 265,000 barrels in new refining capacity to Ontario's existing capacity would suggest that unless a tremendous upsurge in demand for

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[1] Acres' survey, percentage as expressed on Btu basis and is deemed to include all fossil forms of process energy.

petroleum products occurs, there will be ample refinery capacity for all products over at least the next decade and possibly longer.

Conservation

It is obvious that the more energy-efficient a refinery is, the more product it can sell. However, the incentive to reduce energy use depends on more than just technological process energy requirements. Refinery design, market demand and product mix have a tremendous impact on energy use. Approximately one-half of the potential energy savings available to refineries can be accomplished by increasing maintenance staff and spending moderate amounts of capital. The remainder can only be attained through heavy capital investment in new refinery facilities.

Environmental considerations also have a significant impact on process energy use in this industry. It is estimated that the production of lead-free gasoline, the reduction of sulphur content in oil and improvements in water effluent treatment, have increased process energy requirements by approximately 0.6 per cent of crude oil throughput. In terms of 1973 process energy requirements, the above represents an increase in consumption of almost one million barrels of fuel oil equivalent (Btu basis).

Three conservation issues were discussed in the Gordian Associates Study.[1] Briefly the results are:

[1] Gordian Associates, The Potential for Energy Conservation in Nine Selected Industries.

(a) Changing the crude oil from 32° API light crude to 17° API heavy crude required about 25 per cent more energy in the refinery to produce the same products. Current crude used in Ontario typically averages 42° API.[1]

(b) Increasing sulphur content of residual fuel oil from 1.0 per cent to 1.6 per cent decreased total refinery energy requirement by 1.5 per cent.[2] The volume of production of fuel oil was only 6.5 per cent of crude oil intake. In the case of Ontario, residual fuel oil production comprises 14.3 per cent of crude intake. EM&R estimates the sulphur content of the fuels ranges from .75 per cent for No. 4 to 1.5 to 2.0 per cent for No. 6.

(c) The impacts of changing motor gasoline lead levels and octane numbers can be significant. The following examples are for a fixed gasoline production volume and total refinery energy consumption:

Case	Lead Level cc TEL/gal	Octane Number	Relative Energy Used
A	2.0	96.5	1.00
B	0.5	96.5	1.22
C	0.0	92.0	1.09
D	0.5	92.0	0.99

Natural gas is consumed in place of fuel oil or fuel gas when environmental concern (especially SO_2 emissions) overshadow operating efficiency. An example is Gulf's location in the middle of a residential community in Clarkson.

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[1] Marker Crude Western Canada, Nickels' Daily Oil Bulletin.

[2] Less than .1% as an absolute percentage of crude oil intake.

Technology

The petroleum refining industry is presently working on new technology that could eventually reduce process energy requirements. At this time it would be totally speculative to comment on the potential effect of new technology. However, it is important to consider the time frame for possible innovations. For the next decade overcapacity will exist in petroleum refining in eastern Canada. Even if substantial improvements were to become possible within the next five years, installation lead times are such that no significant improvements can be expected before 1985, because of the current overcapacity situation. Thereafter, assuming significant improvements in energy efficiency, only modest overall impact can be expected because of the size and useful life of present facilities.

Three potential technological changes were mentioned in the survey:

- High temperature catalytic cracker regeneration,
- Use of fuel gas in place of steam for atomizing fuel oil,
- Heat cycle equipment to recover process heat from relatively low temperature streams.

The technology exists for all three; however, current economics preclude their use. No further investigation was undertaken in these areas.

Pollution control legislation aimed at reducing the emissions of sulphur dioxide to the atmosphere during the combustion process will require the production of

fuel oils lower in sulphur content. While no specifications or schedules are available, it can be expected that refineries will be required to install more hydrogen desulphurization capacity in the future to meet the new standards.

3.13.6 - Industry Model

There are 8 major energy consuming processes used by petroleum refineries in Ontario. The various outputs from the industry may be viewed as being produced by means of combinations of these processes as outlined in the flow diagram for the industry. These processes are identified in the model as:

- Crude distillation,
- Vacuum distillation,
- Thermal visbreaking,
- Catalytic fluid cracking
- Hydrocracking,
- Hydrogen desulphurization,
- Catalytic reforming,
- Other operations.

Total demand for various refinery products will be provided ultimately by the models for the other industries and sectors. This demand must be assigned to the various processes used in the production of each product.

The nature of the industry is such that each company will first determine the demand for each of its end products, then will use a detailed model of their refinery to

optimize the use of all equipment, given the product mix. In the model presented here no attempt has been made to mirror the optimizing routines that the industry would use. A much more elementary approach has been adopted. The total demand for gasoline and fuel oils,[1] as determined by the various components of the study and expressed in Btu x 10^9, is factored upwards to reflect a total crude oil input to the refinery model. The factor used is the actual ratio of the output of these products to the crude oil input (total run to refinery stills) as listed by Statistics Canada (y). This input is then assigned to the major processes based upon our understanding of and discussions with the industry.

(13.1) ... Qc = (Total demand[1])/y
= Btu x 10^9 of crude oil run to stills, current value of y is .59 (Table 3.13a)

(13.2) ... Qb = Qc/5.803
= Barrels of crude oil run to refinery stills, in thousands.

The assignment to process is discussed below. One hundred per cent of the input is assigned to the crude distillation unit, the current capacity of these units is the total crude oil capacity of the province, i.e. 540,300 barrels per day (calendar day). Economic considerations dictate that the vacuum distillation and the catalytic reforming processes will be fully loaded. Currently these processes have capacities which represent 31.4 and 22.4 per cent respectively of the total crude oil capacity. These percentages were taken to be the optimum operating situation in the refinery, thus 31.4 per cent of the crude oil input as computed by the model will be assigned to

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[1] Consists of motor gasoline, diesel oil and heavy fuel oil.

the vacuum distillation unit and 22.4 to the catalytic reforming unit. If the refineries are running considerably under capacities, these units will obviously not be fully utilized. The cracking plants are assumed to handle 34.6 per cent of the total crude oil input and the hydrogen desulphurization unit 31.6 per cent. The latter unit is assumed to run at 80 per cent of capacity. This data is summarized below:

Unit	Capacity (bbl/cal.day)	% of Crude Capacity (%)	Proportion Assigned[2] (%)
Crude distillation	540,300	100.0	100.0 (p_1)
Vacuum distillation	164,900[1]	30.5	30.5 (p_2)
Cracking plants	186,700	34.6	34.6 (p_3)
Hydrogen desulphurization	212,900	39.4	31.6 (p_4)
Catalytic reforming	121,250	22.4	22.4 (p_5)

The other operations process uses the total crude oil input as its measure of intensity. Thus,

(13.3) ... $q_1 = p_1\ Qb$
= thousands of barrels to crude distillation unit

(13.4) ... $q_2 = p_2\ Qb$
= thousands of barrels to vacuum distillation units

(13.5) ... $q_3 = p_3\ Qb$
= thousands of barrels to cracking plants

[1] Assumes a 22,000-barrel per day unit installed at Sun Oil, Sarnia.

[2] These proportions are based on current refinery configurations and will change as capacities change.

(13.6) ... $q_4 = p_4\ Qb$
= thousands of barrels to hydrogen desulphurization units

(13.7) ... $q_5 = p_5\ Qb$
= thousands of barrels to catalytic reforming.

There are three types of cracking plants: thermal visbreaking, catalytic fluid and hydrocracking. The model assigns total cracking demand on the basis of relative capacities. Currently (1975) these capacities are:

	bbl/day	Per Cent
Thermal visbreaking	38,000	20.4 (p_6)
Catalytic fluid	131,600	70.5 (p_7)
Hydrocracking	17,100	9.1 (p_8)

Thermal cracking is considered to be an obsolete process and is kept on stream because it is more economic to maintain than replace it. Hydrocracking is the newest type of plant and is the most efficient, i.e. it produces more of the light ends than the other methods. However, it is also very expensive and must be fully loaded to be justified.

The distribution among cracking plants is:

(13.8) ... $q_6 = p_6\ q_3$
= thousands of barrels charged to thermal visbreaking

(13.9) ... $q_7 = p_7\ q_3$
= thousands of barrels charged to catalytic fluid

(13.10) ... $q_8 = p_8\ q_3$
$= $ thousands of barrels charged to hydrocrackers

This procedure, obviously short circuits many of the refining operations. Also, no allowance is specifically made for various by-products of one fuel type which are blended into others.

The complex interconnection of refinery methods makes it difficult to compute the energy input per unit of output, (e.g. Btu per gallon of gasoline.) Therefore, total energy demand is related to the intensity at which each process is utilized. In the industry as a whole, rapid and inexpensive substitution among fuels, capability to generate various fuels within the refinery itself, and the use of single energy sources (i.e. charge heaters) in several different processes make the precise specification of energy demand by fuel impractical.

In nearly all of the processing stages of a refinery, energy is required in the form of direct heat to raise the temperature of the oil being processed. Additional energy is required for mechanical drives to force the oil through the process. The heat is supplied to the process either directly or in the form of steam produced from either purchased, non-purchased or by-product sources. Natural gas, heavy fuel oil and fuel gas[1] respectively are the major fuel types for each source. Electricity provides power for mechanical drives, e.g. compressors, pumps, etc.

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[1] Process tail gas.

Energy consumption by process is expressed in terms of the steam, direct fuel and electricity requirements per unit charge to the process. Total steam and direct fuel demands are apportioned among the three major fuel sources: natural gas, fuel oil and fuel gas (process tail gas). Natural gas and electricity are purchased, fuel oil and fuel gas are obtained from the refining itself.

Per unit energy requirements were obtained from the literature and confirmed by the survey. Consumption by fuel type was computed from historical data. Total consumption of natural gas, fuel gas[1] and fuel oil for 1973 was $3,250 \times 10^9$, $28,693 \times 10^9$ and $34,239 \times 10^9$ Btu respectively. The proportions are:

	Btu x 10	Per Cent
Natural gas	3,250	4.9 (p_9)
Fuel oil	34,239	51.7 (p_{10})
Fuel gas[1]	28,693	43.4 (p_{11})

Energy consumption by fuel is calculated as:

(13.11) ... Qh = total steam plus total direct fuel requirement in Btu x 10^9

(13.12) ... $q_9 = p_9\ Qh$
= natural gas consumption, (Btu x 10^9)

(13.13) ... $q_{10} = p_{10}\ Qh$
= fuel oil consumption, (Btu x 10^9)

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[1] Fuel gas consumption includes some minor constituents of own consumption, see Table 3.13a.

(13.14) ... $q_{11} = p_{11}\ Qh$

= fuel gas consumption, including own consumption of other minor constituents, (Btu x 10^9)

All of the fuel gas produced in the refining operations is used in the various processes to offset consumption of purchased fuels or saleable products. Currently the amount of fuel gas produced is equivalent, on a Btu basis, to 2.96 per cent of total crude oil input.

TABLE 3.13a

ESTIMATES OF OUTPUT - PETROLEUM REFINERIES
ONTARIO, 1964 - 1973

(thousands of barrels)

Year	Motor Gasoline	Kerosene	Diesel Oil	Light Fuel Oil	Heavy Fuel Oil
1964	38,993	4,054	6,841	20,238	17,152
1965	40,729	4,205	8,238	21,376	18,491
1966	42,388	3,922	8,742	21,524	20,131
1967	42,818	4,070	8,394	19,980	20,880
1968	45,691	4,013	9,634	22,121	20,809
1969	48,456	4,896	10,640	22,542	19,202
1970	51,876	5,418	11,133	25,357	21,505
1971	53,769	4,804	11,456	27,100	20,094
1972	57,631	4,730	11,544	24,632	18,722
1973	61,033	6,050	12,099	25,417	19,889

Source: Statistics Canada, 45-204 and 45-004.

TABLE 3.13a (cont'd)

PETROLEUM REFINERIES -- ONTARIO 1973
PRODUCTION AND OWN CONSUMPTION

	Production		Own Consumption		Conversion Rate
	(bbl x 10^3)	(Btu x 10^9)	(bbl x 10^3)	(Btu x 10^9)	(Btu x 10^6/bbl)
Crude oil input	150,264	871,983	-	-	5.8030
Propanes	1,961	7,528	16	60	3.8400
Butanes	432	1,857	21	92	4.3000
Petrochemical feed	6,901	40,216	86	500	5.8275
Naptha specialties	2,128	12,400	16	90	5.8275
Aviation gasoline	59	296	-	-	5.0505
Motor gasoline	61,033	318,713*	64	333*	5.2220
Aviation turbo fuel	4,951	26,808	16	84	5.4145
Kerosene	6,050	34,348	5	27	5.6770
Diesel fuel oil	12,099	70,504*	149	866*	5.8275
Light fuel oil (2,3)	25,417	148,116	53	311	5.8275
Heavy fuel oil (4,5,6)	19,889	125,050*	5,446	34,239*	6.2874
Asphalt	3,102	18,079	-	-	5.8275
Coke	4	23	-	-	5.3852
Oil and grease	1,427	8,316	11	65	5.8275
Still gas	3,960	24,901	4,099	25,770	6.2874
Other	1,471	8,570	85	493	5.8275
Losses	-770	-4,487	-	-	5.8275
TOTAL	150,113	841,238	10,065	62,932	-

*) Components of model demand: 514,267 x 10^9 Btu (59.0% of input)

Source: Statistics Canada, 45-004. (Totals may not add due to rounding)

TABLE 3.13b

PER UNIT ENERGY REQUIREMENTS
PETROLEUM REFINERIES

(Btu x 10^6/unit)[1]

Production Process (variable)		Energy Form: Direct Heat	Steam[4]	Electricity
Crude distillation[2]	(q_1)	67.0	20.0	1.02
Vacuum distillation[2]	(q_2)	60.0	53.3	1.71
Thermal visbreaking[2]	(q_6)	260.0	-106.7	6.14
Catalytic fluid[2]	(q_7)	105.0	-133.3	8.53
Hydrocracking[2]	(q_8)	145.0	-8.0	27.98
Hydrogen desulphurization[2]	(q_4)	66.0	33.3	5.8
Catalytic reforming[2]	(q_5)	380.0	-	10.24
Other operations[3]	(q_1)	152.0	42.2	0.013

[1] Units are thousands of barrels charged to process.

[2] Gordian Associates.

[3] Includes polymerization, alkylation, blending, coking, etc. The per unit figures are those required to balance the model to 1973 Statistics Canada total energy figures and to the ratio of steam to direct heat expressed in the Gordian Associates study.

[4] Based on 1,333 Btu per pound of steam (86% efficient boiler).

3.14 - Pulp and Paper

3.14.1 - Industry Overview - Energy Use

During 1973 Ontario pulp and paper manufacturers consumed more than 73.7×10^{12} Btu of energy. In addition, this industry has waste products such as bark, sawdust, etc. and residues from the chemical pulping process to generate steam and electricity. An Ontario Hydro report[1] estimates that this is equivalent to 22 per cent of purchased fuels, approximately $16,154 \times 10^{9}$ Btu.

Purchased energy sources for this industry are coal, fuel oil, natural gas and electricity. Waste material such as bark, spent liquor and sawdust are used wherever it is economically feasible to do so. Interchangeability between alternate fossil fuel forms (coal, oil, natural gas) is possible to a substantial degree. The main reason for the high possibility of substitution in the pulp and paper industry is that much of the fuel is used for boilers and is therefore, not tied to specific processes or technologies. Limitations to substitutability do exist and particularly for coal. Many sites would not have sufficient storage and handling equipment readily available to allow a short-term substitution of coal although, of course, in the longer run this could be achieved.

3.14.2 - Industry Overview - Markets

Of Canada's major primary industries, none is more export-oriented than pulp and paper, particularly its newsprint and market pulp component. Approximately 32 per cent of

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[1] Energy Use in Pulp and Paper Mills in Ontario.

wood-pulp and over 90 per cent of newsprint produced by the Canadian industry is for the export market. The United States consumes close to 60 per cent of the wood pulp and over 80 per cent of the newsprint exported from Canada.[1]

To gain an understanding of the Ontario pulp and paper industry, it is essential to view it in terms of its major elements, each of which are outlined below.

Newsprint

On a tonnage basis, newsprint is the most important product of this Canadian and Ontario industry. Of Ontario's 1973 production of basic paper and paperboard, newsprint accounted for 69 per cent of total tonnage.[2]

Until the 1950's, northern softwood species were considered the best newsprint fibre. Canada and Scandinavia supplied practically all of the world market requirements for this product. Then, in the early 1950's the manufacture of newsprint of acceptable quality from southern U.S. softwood was rapidly achieved. As a result, the Canadian share of the U.S. newsprint market slipped from 80 per cent in 1950 to 65 per cent in 1973.[1]

From an efficiency point of view, it is important to compare recent operating ratios of Canadian and United States newsprint mills. Between 1965 and 1974, Canadian mills operated at an average 88.8 per cent of capacity, whereas American mills were able to achieve a remarkable 96.3 capacity utilization average.[1] This is primarily

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[1] Canadian Pulp and Paper Association.

[2] Statistics Canada, 36-204.

the result of the fact that U.S. production of newsprint is only one-third of market demand and plants can therefore achieve a high level of output through all types of market conditions, while Canadian producers must withstand swings in demand.

Fine Papers

This category, consisting primarily of communications papers, is manufactured mostly for the domestic market.

The relatively small size of the Canadian fine papers market requires manufacturers to resort to short and expensive production runs. Thus Canadian fine papers are subject to substantial foreign competition, mainly from the United States. There the large size of the American fine papers market enables manufacturers to enjoy long production runs which are reflected in lower operating costs.

More than half of the Canadian fine papers industry is concentrated in Ontario. The manufacture of this product is much more labour-intensive than newsprint in the finishing operation.

Linerboard Material

Pulp from which part of the lignin has been removed and some recycled paper are used for linerboard. The market is primarily domestic with little export.

Consumer Products

This product group consists of such items as towelling, napkins, tissue papers and disposables. It represents,

on a volume basis, a small portion of the pulp and paper production. Even though the market is primarily domestic, it is highly competitive, characterized by intense point of sale promotion.

Market Pulp

Though Ontario is not now a major producer of market pulp as an export commodity, new plant expansions could change that picture.

3.14.3 - Production Process

The manufacture of pulp and paper and other paper products consists of many complex processes. Here only a brief overview is possible. The production of most paper and paperboard products generally follows this sequence:

- Pulpwood acquisition, harvesting of roundwood and procurement of sawmill residues (chips),
- Debarking and chipping of roundwood;
- Pulping, either chemical or mechanical or both,
- Pulp bleaching (and drying for market pulp),
- Paper and/or paperboard production.

Pulping

The manufacture of paper begins with the manufacture of pulp, usually but not always from wood. The purpose of pulping, either mechanical or chemical, is to reduce the wood to fibres which will adhere one to the other as water is removed.

(a) Mechanical

Mechanical pulping reduces debarked logs to a fibrous condition by pressing them against rotating grindstones. Groundwood or mechanical pulp contains all of the components of wood with the yield being 95 per cent or higher. Groundwood pulp is used primarily in the manufacture of newsprint.

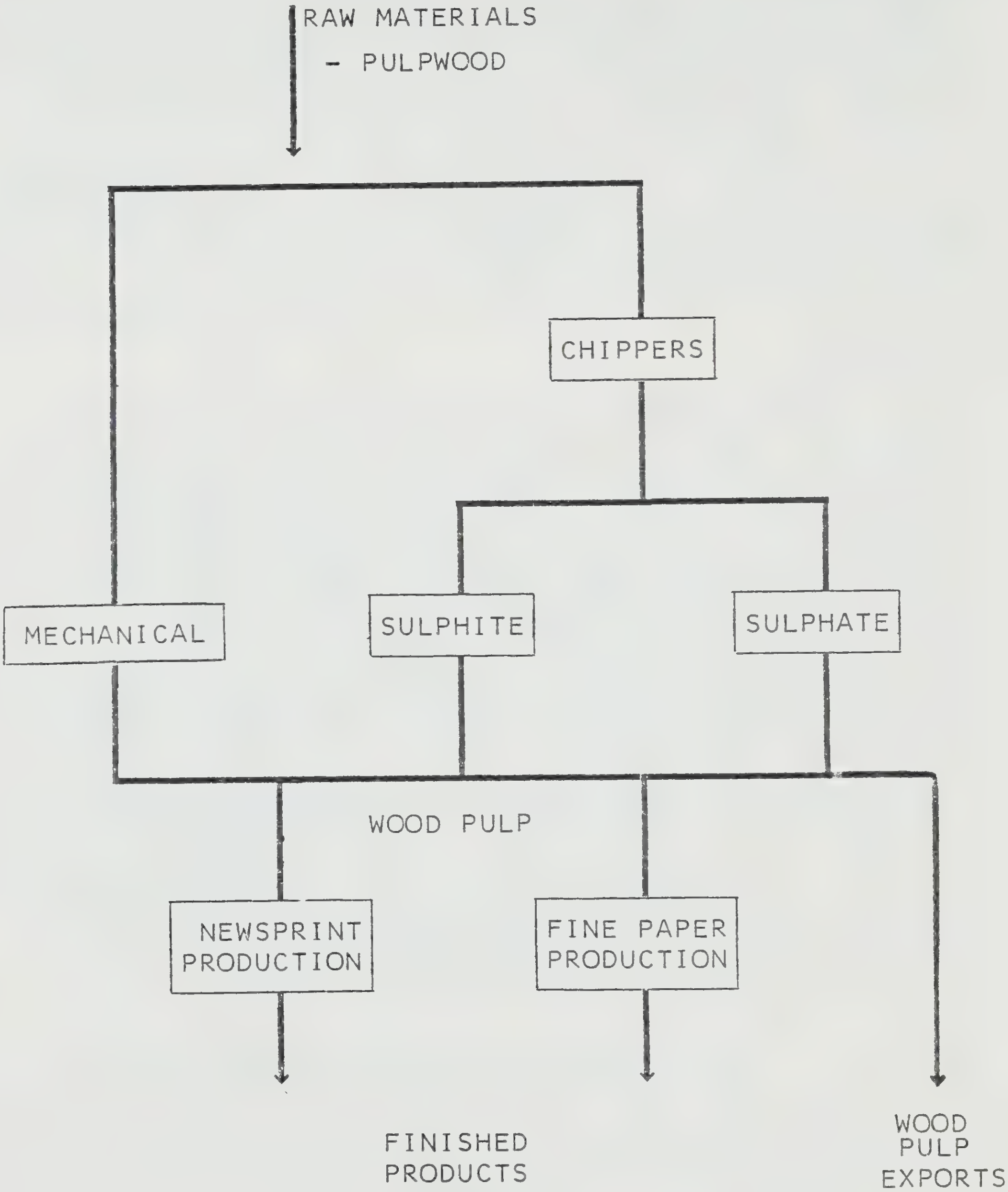
(b) Chemical

Chemical pulping separates the cellulose fibres by dissolving the lignin that binds them. The logs are initially converted to chips which are cooked under pressure in a chemical solution called "liquor". This cooking dissolves virtually everything except the fibres so that the yield from chemical pulping is about half the weight of wood. Though the yield is much lower than for groundwood pulp, strength and other properties of chemical pulps are necessary for most paper and paperboards. Newsprint contains between 12 and 25 per cent chemical pulp, while fine papers are made from nearly 100 per cent chemical pulp for such items as consumer products and packaging materials.

The two principal chemical pulping methods are "sulphate" (or kraft) and "sulphite" pulping, the major difference being that the sulphate cooking liquor is an alkali and the sulphite liquor is an acid.

Sulphate pulp: In sulphate or kraft pulping, the wood chips are cooked in an alkaline solution. The spent liquor from the digesters, containing the chemicals and about half of the original wood is evaporated to remove most of the water and is then burned in a recovery

PRODUCTION PROCESS
PULP AND PAPER



furnace. There the organic material burns, providing a source of heat for raising steam. The chemicals are recovered for reuse.

Sulphite pulp: Here there is relatively little opportunity for the use of waste material for the replacement of fossil fuels. Use of the sulphite pulping method is on the decline because of the difficulties associated with the disposal of environmentally undesirable waste materials.

Papermaking

The manufacture of paper is a highly complex process. Essentially it consists of placing a mixture of cellulose fibres (pulp) and water, in an even layer, on a continuous rapidly moving screen and removing the water through pressure, suction and heat.

A surprising range of paper grades contain recycled waste paper. In fact, some paper mills, particularly those where boxboard is manufactured, are dependent on waste paper for nearly all of their raw material. Other mills making fine and sanitary papers use substantial amounts of repulped paper.

Secondary fibre, as the waste is called, is available in a wide variety of grades ranging from clean white trimmings that command a premium price to mixed household papers and office waste. The presence of contaminants is a serious impediment to more widespread use of secondary fibre. Ironically, as technology in other industry improves and quality of inks, adhesives and plastic coatings, these have become more difficult to separate from the usable fibre in the pulp and paper industry.

3.14.4 - Energy Consumption

The most energy-intensive process in the manufacture of paper products is the manufacture of pulp. Since the range of pulp produced is so great, it is most useful to examine typical values such as are listed below. The energy inputs are given in pounds of steam per ton of product and in millions of Btu.[1]

Typical steam requirement for pulp:

Product	Steam Requirements/Ton (pounds)	Steam Requirements/Ton (Btu x 10^6)[1]
Unbleached kraft pulp for liner-board - 5-6% moisture content	5,000	6.7
Unbleached corrugated medium pulp	3,200	4.3
Unbleached sulphite pulp for newsprint furnish	5-6,000	6.7-8.0
Semi-bleached kraft pulp for newsprint furnish	8,300	11.1
Unbleached sulphite market pulp baled and dried for shipment - 5-6% moisture content	8,500	11.3
Bleached hardwood kraft pulp for fine paper	11,000	14.7
Bleached hardwood kraft pulp, baled and dried for shipment	16,000	21.3
Bleached softwood kraft pulp for fine paper	15,000	20.0
Bleached softwood kraft pulp for fine paper, baled and dried for shipment	19,500	26.0

Source: Acres' survey.

[1] Based on 1,333 Btu per pound of steam.

The pulp and paper industry requires electricity for mechanical drive and fossil fuel, primarily for steam generation. Of the total purchased energy requirement, electricity represents approximately 20 per cent, with fossil fuels accounting for the remaining 80 per cent.

Ontario pulp and paper mills use oil, coal, natural gas or a combination of any of these to generate process steam. Natural gas is used for some direct-fired drying applications.

Over the past decade, natural gas has displaced most of the coal as the principal fossil fuel. The change has been prompted by pollution regulations, favourable natural gas prices and reduced handling charges. As new boilers were required, boiler design was simplified by making gas with fuel oil stand-by the only firing requirements. Coal firing systems on many older boilers were eliminated.

The pulp and paper industry depends primarily on price and availability in choosing its fuels. Most plants have at least dual-fuel, gas/oil firing capability which makes it possible to take advantage of any price differences. Switch-over from oil to gas boiler firing is a relatively simple and short procedure that can take place without loss of production or efficiency.

Energy consumption by major product group is described below:

<u>Newsprint</u>

Steam and electrical requirements are in the order of 9,000 lbs and 1,700 kwh per ton respectively. On a Btu basis, the above represents a total of 18 million Btu per

ton, with electricity representing almost 33 per cent of the total energy requirement.

Fine Papers

Fine papers are produced from fully bleached sulphate or kraft pulp. The kraft process lends itself to the use of waste material for steam and even electrical power generation.

Of the 25,000 lbs of steam required for the manufacture of one ton of fine paper, approximately one-half, or 12,000 lbs can be generated in a recovery furnace fueled by spent liquor.

Electrical requirements are approximately 1,100 kwh per ton.

Fully Bleached Kraft Market Pulp

The production of market pulp requires a much lower overall energy input than for fine papers. At least 20,000 lbs less steam and 750 kwh less electricity is required per ton. It is possible to generate some 12,000 lbs of steam in a recovery furnace, thus decreasing the need for fossil fuel to the 10.5 million Btu per ton range.

Linerboard

The manufacture of linerboard requires approximately 17,000 lbs of steam and 850 kwh of electricity. Use of a recovery furnace can reduce the amount of purchased steam to 5,000 lbs per ton.

3.14.5 - The Future Outlook

Markets

As intimated in the overview, there are indications that Canada and Ontario may be losing some of their competitive edge in export to the U.S. where new resources and higher plant utilization factors favour maximum production in the U.S. At the same time, the U.S. resource is limited and Canada is still a major source of supply. Over the longer run this is likely to continue and even in Ontario the resource is, to some degree, limited. Therefore, if demand for pulp and paper on a worldwide basis continues to expand, a vigorous market should be assured and hence a continued high level of activity for the industry in Ontario. The level of activity will be tied to overall Canadian and American economic activity.

Conservation

As in other industries, some savings can be achieved without major investments, while other potential savings will take substantial capital inputs.

Some of the major opportunities for reducing the quantities of purchased energy are outlined below:

Newsprint: There is little opportunity to use waste wood material for fuel in a newsprint mill because newsprint pulp consists normally of only 12 to 25 per cent sulphite pulp with remainder being mechanical pulp. Wood bark, if facilities for its handling are available, can reduce purchases of fossil fuel by up to 10 per cent.

Recent trends towards making lighter weight paper have not yet produced noticeable reductions in fuel use per ton. Quality control makes it difficult to adapt existing old paper machines to a new paper weight while using less fuel in the drying process.

There is normally limited potential for on-site power generation and the electrical and steam loads are not nearly as balanced as in a kraft mill.

Fine papers: Fine papers are normally produced from kraft pulp. With this chemical pulping process, a good balance exists between the steam and electrical power requirements. For this reason, helped further by the possibility of recovering energy from the wood waste dissolved in the chemical liquor, there is an excellent theoretical opportunity of generating most of the kraft mill's electrical requirement. The potential for electric power generation in this industry should be carefully examined.

At the March, 1976 Second Industrial Energy Conference, the pulp and paper industry set a goal of reducing purchased energy per ton of product by 12 per cent by 1980. The base year for measuring such reductions is 1972. Many conditions were specified as being essential to the attainment of such a goal, the most important being an ability to retain earnings to invest in projects to reduce energy use, a favourable economic climate and stable environmental requirements.

The pulp and paper industry also pointed to the potential for major reduction of purchased energy use through on-site energy generation. The two chief energy forms

utilized in this industry -- steam and electricity -- suggest there are possibilities for the economic use of steam turbine installations to generate both. Moreover, the feasibility of this equipment can only be tested in the operating characteristics of each individual plant. Such factors as steam pressure and temperature in the production processes versus that exiting the turbines and the relative costs in replacing existing steam generating facilities must all be analyzed.

An Ontario Hydro Study[1] estimates that a system generating both steam and electricity can achieve efficiency of approximately 85 per cent, compared to a modern fossil-fuel fired electrical generating plant which is typically 39 per cent.

This same report estimates that some 1870 million kwh of electricity was produced in Ontario in self-generation facilities. This figure represents 43 per cent of the purchased electrical energy and 30 per cent of the total electrical energy consumed in the industry. Inexpensive power from Ontario Hydro has made self-generation less popular in Ontario than in European or U.S. mills. Seventy-five per cent of the self generated electricity was in hydraulic stations, the remainder was in thermal installations. The steam used to drive the thermal generators was derived from burning spent liquor from chemical pulping and bark. The excess steam was used elsewhere in the plant.

It is also stated that in kraft (sulphate) mills the burning of bark and spent liquor can generate sufficient

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[1] Energy Use in Pulp and Paper Mills in Ontario.

steam and electricity to run the mill without additional energy. Newsprint mills do not have this capability and must seek energy from external sources.

Technology

Though this section contains a brief discussion of some of the possible technological changes in the production of pulp and paper that could reduce energy inputs, such changes are not contemplated for their energy-reducing potential.

Thermo-mechanical pulping (TMP) has been receiving considerable technical press coverage during the last few years. It is hoped that, when fully developed, this process could totally replace the groundwood and chemical pulp mixture used in newsprint mills. Elimination of chemical pulp would accomplish the following:

- Reduce the complexity of operations;
- Overcome the sulphite pulping pollution problems;
- Improve paper characteristics as compared to stone groundwood;
- Increase pulp yield to between 94 and 97 per cent from the present levels of 50 to 60 per cent from chemical pulp. An integrated lumber-pulp and paper operation would be able to use wood chips and other residues that could not readily be processed. This greater utilization of wood is of distinct advantage, especially to a fully integrated forest product corporation;
- Eliminate the cost of chemicals.

Thermo-mechanical pulping is still in its prototype stage of development. Pulp and paper industry representatives

are not yet sure of the specific gains that can be expected from TMP and whatever operating experience with TMP units has been gained, the results have not been widely publicized.

There are conflicting views concerning total energy use with TMP compared to the conventional sulphite-groundwood pulp mix. Most of the people contacted expressed the view that though electrical energy requirements for newsprint with TMP may be some 20 per cent higher,[1] other factors such as higher yield, better quality and reduced expenditures on chemicals would provide some measure of compensation. In fact, it is not inconceivable that as wood costs escalate, the greater total yield of TMP may more than compensate for a higher total energy consumption.

3.14.6 - Industry Model

For purposes of this study, the pulp and paper industry has been divided into seven major energy-related processes. The energy form which dominates these processes is steam. The fuel requirements therefore must reflect the steam source. The processes are:

- Mechanical pulping,
- Sulphite pulping,
- Sulphate pulping
- Newsprint production,
- Fine paper production,
- Chipping of pulpwood,
- Other operations.

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[1] Ontario Hydro estimates that current electricity requirements for TMP is 100 hp/day/ton or 6.1 million Btu/ton, no steam requirement was available.

The first three processes deal with the transformation of wood to pulp and the next two with pulp to paper and the sixth process with a mechanical operation preceding either sulphite or sulphate pulping.

The output measures of the pulp and paper industry are two: tons of newsprint produced and tons of fine paper products. The newsprint production has been tied to the American Gross National Product to accommodate the large volume of exports. Fine paper production is related to the domestic market through the Canadian Gross National Product.

(14.1) ... $Qn = 1{,}385{,}295 + 0.61\ (USGNP)$

(14.2) ... $Qf = 138{,}364 + 13.2\ (GNP)$

These output figures are then assigned to the various wood pulp producing processes: mechanical, sulphite and sulphate. There are no rigid rules to this assignment within the industry other than the fact that newsprint is primarily produced from mechanical wood pulp and fine papers are primarily from chemical wood pulp. The following proportions have been assumed:

	Newsprint	Fine Papers
Mechanical	0.881(p_1)	0.00 (p_2)
Sulphite	0.119(p_3)	0.214(p_4)
Sulphate	0.00 (p_5)	0.786(p_6)

Thus, newsprint is assumed to be produced from 88.1 per cent mechanical groundwood pulp and 11.9 per cent sulphite wood pulp. Fine papers are produced from 21.4 per cent sulphite and 78.6 per cent sulphate wood pulp. Conversely

100 per cent of the mechanical wood pulp is used in newsprint, 100 per cent of the sulphate is used in fine papers and sulphite wood pulp is split between the two. The proportions chosen above typify the industry over the past decade and were computed from 1973 data, and discussions with the industry. Thus,

(14.3) ... $q_1 = p_1\ Qn + p_2\ Qf$
= tons of mechanical groundwood pulp required to satisfy domestic production of newsprint and fine papers.

(14.4) ... $q_2 = p_3\ Qn + p_4\ Qf$
= tons of sulphite wood pulp required to satisfy domestic production of newsprint and fine papers.

(14.5) ... $q_3 = p_5\ Qn + p_6\ Qf$
= tons of sulphate wood pulp required to satisfy domestic production of newsprint and fine papers.

Total production of wood pulp by process includes the above figures plus allowance for export of wood pulp. No wood pulp production or export data by process was available at the provincial level. National data and provincial totals were used to estimate the export demand for wood pulp by process.

At the national level in 1973 the pulp and paper industry exported 6,517,000 tons of wood pulp or 31.8 per cent of total production. The exports by process, in relation to total production by process, were 60.9 per cent of total sulphate wood pulp was exported, 22.2 per cent of sulphite and 3.3 of mechanical groundwood pulp. The distribution of exports was 83.7 per cent sulphate, 8.3 per cent sulphite, 4.3 mechanical and 3.7 per cent other types of wood pulp.

Ontario produced a total of 4,044,364 tons of wood pulp of which some 3,117,000 tons can be accounted for in domestic consumption. This latter figure is not precise as there are several minor classifications of wood pulp consumed in the province. On a national basis these other classifications total 3.5 per cent of the total wood pulp production. The 1973 exports of Ontario wood pulp is estimated at 927,000 tons. The data is summarized below:

	Wood Pulp (Tons x 10^3)					
	Production[3]		Used[3]		Exports[4]	
	Canada	Ontario	Canada	Ontario	Canada	Ontario
Total	20,462	4,044	13,762	3,117[2]	6,517	927[2,3]
Mechanical	8,372	-[1]	8,128	1,687	279	-[1]
Sulphite	2,488	-[1]	1,906	576	542	-[1]
Sulphate	8,893	-[1]	3,329	854	5,457	-[1]
Other	709	-[1]	399	-[1]	239	-[1]

The exports so calculated have been related to the American Gross National Product in constant dollars. (The United States accounts for some 60 per cent of wood pulp exports). The export demand is distributed by process using the national data, as no provincial figures exist.

(14.6) ... $Qe = 244{,}364 + 0.96\ (USGNP)$

= total tons of wood pulp (from all processes) exported from Ontario.

(14.7) ... $q_4 = p_7\ Qe$

= tons of export wood pulp produced in mechanical process, 1973 value of $p_7 = 0.043$

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[1] Not available.

[2] Estimate.

[3] Statistics Canada, 36-204.

[4] Canadian Pulp and Paper Association.

(14.8) ... $q_5 = p_8 \, Qe$
$= $ tons of export wood pulp produced in sulphite process, 1973 value of $p_8 = 0.083$

(14.9) ... $q_6 = p_9 \, Qe$
$= $ tons of export wood pulp produced in sulphate and other processes, 1973 value of $p_9 = 0.874$

The chippers are used to prepare the pulpwood for the chemical wood pulp production processes. Thus, the total production of chemical wood pulp ($q_2 + q_3 + q_5 + q_6$) is the output measure associated with the chippers.

(14.10) ... $PULPC = q_2 + q_3 + q_5 + q_6$
$= $ tons of chemical wood pulp produced.

The throughput of the "other operations" process is expressed as the total tons of finished paper products -- newsprint and fine papers -- from the industry. This category includes debarking, special pulping processes, bleaching operations not associated with the three pulping and two product processes listed separately, materials handling, etc. The per unit energy requirements for this process are computed as these figures required to balance the model to the 1973 total energy consumption data.

Energy consumption occurs in essentially two forms: electricity and steam. All of the steam and some of the electricity is produced on-site. The boiler fuel is either fuel oil, natural gas, coal or non-purchased fuels such as wood waste or spent liquor. The proportions of each have been estimated from what little data is available. The Ontario Hydro report, previously cited, provides the most detailed analysis of energy consumption

in this industry for 1972. This was supplemented by Statistics Canada figures for the same year to obtain the proportions listed below.

APPARENT ENERGY CONSUMPTION
PULP AND PAPER INDUSTRY
1972

Source	Energy Form Used: Steam (Btu x 10^9)	Steam (%)	Electricity (Btu x 10^9)	Electricity (%)
Self-generation:				
- Hydro			4,777	22.7(f_5)
- Thermal(waste)	9,784	14.1(f_1)	1,604	7.6(f_6)
Purchased:				
- Coal	7,509	10.8(f_2)	-	
- Natural gas	37,094	53.3(f_3)	-	
- Fuel oil	15,175	21.8(f_4)	-	
- Electricity	-		14,688	69.7(f_7)
Total	69,562	100.0	21,069	100.0

Source: Ontario Hydro and Statistics Canada.

These proportions (f_1 to f_7) are then applied to the computed demands for steam and electricity to determine the quantities of the ultimate energy sources. The Hydro study implies that the equipment used for self generation is near capacity. Expansion in the industry could be expected to include a proportionate increase in this capability, provided that the direction of the expansion is not solely in the area of newsprint production. Balanced expansion,

i.e. including increases in the sulphate process, would increase the supply of the major fuel for self-generation, the spent liquor. If industrial expansion is not so balanced, the proportion would have to be re-estimated on the basis of the generating capabilities of the industry.

TABLE 3.14a

VARIABLES IN OUTPUT FORECASTING EQUATIONS

Year	Dependent Variables			Independent Variables	
(t)	(Qn)	(Qf)	(Qe)	(GNP)	(USGNP)
1964	1,714,166	1,054,260	824,638	65,610	580,000
1965	1,734,406	1,075,700	745,888	69,981	617,800
1966	1,848,946	1,131,294	831,670	74,844	647,800
1967	1,815,823	1,130,665	869,058	77,344	675,200
1968	1,759,814	1,193,335	918,582	81,864	707,200
1969	1,923,842	1,257,822	1,012,977	86,225	725,600
1970	1,857,570	1,320,467	1,023,344	88,390	722,500
1971	1,773,562	1,345,415	957,113	94,115	746,300
1972	1,790,532	1,444,813	1,068,833	99,680	792,500
1973	1,950,176	1,612,379	927,712	106,854	839,200

where, Qn is total provincial output, in tons, of newsprint, Statistics Canada, 36-204

Qf is total provincial output, in tons, of fine papers, Statistics Canada, 36-204

Qe is total provincial exports, in tons, of wood pulp, computed from Statistics Canada, 36-204

GNP is Canadian Gross National Product in millions of 1971 dollars

USGNP is United States Gross National Product in millions of 1958 dollars.

TABLE 3.14a (cont'd)

PROCESS OUTPUT - PULP AND PAPER
1964 - 1973

(tons)

Year (t)	Wood Pulp Used[1] Mechanical[2] (q_1)	Sulphite (q_2)	Sulphate (q_3)	Wood Pulp Production All Processes
1964	1,462,872	653,438	376,356	3,317,304
1965	1,545,067	657,641	408,157	3,356,753
1966	1,637,170	662,310	455,427	3,586,577
1967	1,604,117	606,453	539,144	3,618,772
1968	1,561,483	595,379	568,595	3,644,039
1969	1,694,325	681,312	572,430	3,961,044
1970	1,654,693	631,991	659,046	3,969,074
1971	1,604,755	575,790	662,482	3,800,140
1972	1,553,241	532,998	782,573	3,937,645
1973	1,687,115	575,594	853,943	4,044,364

[1] Total amount of wood pulp used as input to all papermaking processes in Ontario.

[2] Includes groundwood pulp, screenings, defibrated and exploded wood pulp.

Source: Statistics Canada, 36-204.

TABLE 3.14b

PER UNIT ENERGY REQUIREMENTS
PULP AND PAPER

(Btu x 10^6/unit)[4]

Production Process (variable)	Energy Form	
	Steam[1]	Electricity
Mechanical pulping ($q_1 + q_4$)	-	5.2[2]
Sulphite pulping ($q_2 + q_5$)	6.7[2]	2.5[2]
Sulphate pulping ($q_3 + q_6$)	14.3[2]	2.5[2]
Newsprint production (Qn)	6.0[2]	0.8[2]
Fine paper production (Qf)	12.9[2]	1.0[2]
Chippers (PULPC)	-	0.3[3]
Other operations (Qn + Qf)[5]	2.5	0.7

1 At 1,333 Btu/lb, i.e. 86 per cent boiler efficiency.

2 Gordian Associates, Acres' survey, and Ontario Hydro.

3 Acres' survey.

4 Units are tons of output by process as described in text.

5 Computed to balance 1972 Statistics Canada and Ontario Hydro total energy consumption data.

3.15 - Other Manufacturing

In 1973, energy consumption in the industrial sector was divided by subsector as follows:

	Btu x 10^9	Per Cent
Agriculture	34,145	4.2
Primary manufacturing	674,459	82.0
Other manufacturing	113,746	13.8
Total	822,350	100.0

The preceding 14 sections of this report have attempted to cover the major energy consuming processes in the agriculture and primary manufacturing sectors. This section deals with energy consumption in those industries which individually are not large consumers of power or fuel but collectively consume considerable amounts of energy. As a group, this classification would stand third in overall energy consumption among the 15 sectors covered. Iron and Steel is first and Industrial Chemicals second.

The activities which fall into the "other" category are many and varied. They include manufacturers of clothing, leather, furniture, fabricated metal products, machinery, electrical products and scientific equipment. Of the 12,395 establishments classified to total manufacturing, 10,205 would be in this "other" category. This 82.3 per cent of the industries accounts for slightly over 50 per cent of the value of manufacturers' shipments.

This sector also includes, by default, the energy consumption associated with the minor "other operations" in many of the 14 previous sectors. When these operations, such

as lighting and space heating, were considered to be major energy consumers, there was an explicit process included in the sector, otherwise they would be included here.[1]

Energy consumption in this sector was composed of three primary purchased forms: natural gas (48%), fuel oil (27.5%) and electricity (20.5%). Coal, gasoline, and L.P.G. combined to form the remaining 3.6 per cent.

The nature of the items produced in this category requires that the output measure chosen for the other manufacturing sector be the total value of shipments from each industry in the sector deflated by the appropriate price index to 1971 dollars.[2] The value of shipments is related to the Canadian Gross National Product (also in 1971 dollars).

(15.1) ... $Q_t = 1{,}265{,}590 + 135.5\ (GNP)$

The per unit energy consumption data are based on the historical requirements of the sector and balanced to 1973 Statistics Canada figures.

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[1] Five industries fall under this classification: cement, clay, glass, iron and steel, and lime. No explicit allowance has been made for energy consumed in "other operations" in these industries.

[2] Statistics Canada, Industrial Selling Price Indexes (62-528 and 62-002).

TABLE 3.15a

VARIABLES IN OUTPUT FORECASTING EQUATION

Year	Dependent Variable	Independent Variable
(t)	(Q_t)	(GNP)
1964	9,700,622	65,610
1965	10,586,643	69,981
1966	11,809,069	74,844
1967	12,054,737	77,344
1968	12,582,866	81,864
1969	13,295,048	86,225
1970	13,001,603	88,390
1971	13,610,956	94,115
1972	14,657,077	99,680
1973	15,819,646	106,845

where, Q_t is total output in thousands of constant 1971 dollars,

GNP is Canadian Gross National Product in millions of constant 1971 dollars.

TABLE 3.15b

PER UNIT ENERGY REQUIREMENTS
OTHER MANUFACTURING

(Btu x 10^6/unit)[1]

Production Process (variable)	Energy Form: Fuel Oil	Natural Gas	Coal	Elec-tricity
Total shipments (Q_t)	1.95	3.43	0.03	1.46

[1] Units are thousands of 1971 dollars.

APPENDICES

APPENDICES

APPENDIX A
REGRESSION EQUATIONS

APPENDIX A

REGRESSION EQUATIONS

The following regression equations were used to derive the forecasts of output for the model. The equations are listed by section number and equation number. Standard errors, multiple regression coefficients and Durbin-Watson statistics are shown.

While many of the equations indicate a low level of correlation, it must be remembered that the primary objective of this study was not to present a definitive forecast but rather to investigate the energy-related issues within the industry. The forecasts served only to test the energy model. Improved forecasts of the output measures should therefore precede any detailed forecasting effort.

3.1 - Abrasives

(1.1) ... $50,205 + 0.015\ (AUTOP_{t-1})$

(0.004)

R2 = 0.61 DBW = 1.77

3.2 - Agriculture

(2.3) ... $-86,826 + 22.8\ (POP)$

(1.48)

R2 = 0.96 DBW = 1.80

(2.5) ... $-17,048 + 5.37\ (POP)$

(1.05)

R2 = 0.74 DBW = 0.99

(2.8) ... 529,782 + 72.7 (POP)
(20.7)
$R2 = 0.56$ DBW = 1.72

3.4 = <u>Cement</u>

(4.1) ... 924,998 + 246.5 (CCON)
(55.8)
$R2 = 0.67$ DBW 2.11

3.5 - <u>Clay Products</u>

(5.1) ... 165,485 + 50.7 (OCON) - 49,652 (DUMMY 1970, 1971)
(14.7) (16,811.7)
$R2 = 0.59$ DBW = 1.44

3.6 - <u>Food and Beverages</u>

(6.1) ... -747.5 + 0.577 (POP)
(0.03)
$R2 = 0.97$ DBW = 1.72

3.7 - <u>Glass</u>

(7.1) ... -241,142 + 45.76 (POP)
(4.85)
$R2 = 0.91$ DBW = 2.17

(7.2) ... 8,377 + 0.846 (OCON) + 0.074 (OAUTO)
(9.02) (0.02)
$R2 = 0.96$ DBW = 1.88

3.8 - Industrial Chemicals

(8.1) ... -148,137 + 0.221 (PULPC)
(0.02)
$R2 = 0.93$ DBW = 2.09

(8.3) ... -94,909 + 3.19 (GNP)
(0.23)
$R2 = 0.96$ DBW = 1.27

3.9 - Iron Foundries

(9.1) ... 53,642 + 0.07 (AUTOP) + 2.82 (GNP)
(0.022) (1.697)
$R2 = 0.71$ DBW = 1.67

3.10 - Iron and Steel

(10.1)... 2,279,372 + 63.6 (GNP) + 2.09 (OAUTO)
(56.7) (3.36)
-1,932,618 (DUMMY 1969)
(539,737)
$R2 = 0.93$ DBW = 2.18

3.11 - Lime

(11.1)... 746,792 + 0.08 (PULPC) + 0.02 (STEEL)
(0.115) (0.026)
-131,129 (DUMMY 1967)
(62,195)
$R2 = 0.59$ DBW = 2.35

3.12 - Mining, Milling, Smelting and Refining

(12.1) ... 0.265 (USGNP)
(0.01)
R2 = 0.70 DBW = 2.39

(12.2) ... -27,777 + 0.41 (USGNP)
(0.12)
R2 = 0.55 DBW = 2.10

(12.3) ... -388,378 + 1.01 (USGNP)
(0.12)
R2 = 0.92 DBW = 1.82 (1967-1973 data only)

3.14 - Pulp and Paper

(14.1) ... 1,385,295 + 0.61 (USGNP)
(0.27)
R2 = 0.31 DBW = 2.14

(14.2) ... 138,364 + 13.2 (GNP)
(0.898)
R2 = 0.96 DBW = 1.22

(14.6) ... 244,364 + 0.96 (USGNP)
(0.31)
R2 = 0.49 DBW = 1.66

3.15 - Other Manufacturing

(15.1) ... 1,265,590 + 135.5 (GNP)
(8.51)
R2 = 0.97 DBW = 1.03

DEFINITIONS OF VARIABLES

Independent Variables

The following independent (or driving) variables were used in the study. Each is listed below with its units, source, and variable name assigned in the model.

AUTOP - North American Automobile Output

Units : Number of vehicles

Source : Canadian Motor Vehicle Manufacturers Association

POP - Ontario Population

Units : Thousands

Source : Ontario Statistics 1974, Tables 2.1, 2.2

GNP - Canadian Gross National Product

Units : Millions of constant 1971 dollars

Source : Bank of Canada Review, Table 52

OCON - Ontario Residential and Non-residential Construction Investment

Units : Millions of constant 1971 dollars

Source : Ontario Statistics 1975, Table 11.2 (converted to constant dollars using G.N.E. implicit price indices)

CCON - Canadian Residential and Non-residential Construction Investment

Units : Millions of constant 1971 dollars

Source : Bank of Canada Review, Table 52 (converted to constant dollars using G.N.E. implicit price indices)

USGNP - United States Gross National Product

Units : Millions of constant 1958 dollars

Source : Statistical Abstract of the United States

DUMMYx - Dummy variables used in the derivation of the regression equations to remove unusual shifts in the data series, e.g. loss of production due to strikes.

Dependent Variables

Several other data series are used as dependent variables in the output forecast equations; however, these are computed endogenously as dependent variables and will not be discussed in detail here. These variables are:

ACRES - Ontario Agricultural Land Acreage (section 3.2)

OAUTO - Ontario Automobile Output (section 3.3)

STEEL - Ontario Steel Output (section 3.10)

PULPC - Ontario Chemical Wood Pulp Output (section 3.14).

INDEPENDENT VARIABLES

YEAR	AUTOP	POP	GNP	OCON	CCON	USGNP
Historical values:						
1963	8,162,453					
1964	8,293,600	6,631.0	65,610	2,396	7,829	580,000
1965	9,996,586	6,788.0	69,981	2,416	8,455	617,800
1966	9,292,381	6,960.9	74,844	2,801	8,942	647,800
1967	8,150,848	7,127.0	77,344	2,804	8,634	675,200
1968	9,714,007	7,262.0	81,864	3,064	9,062	707,200
1969	9,260,490	7,385.0	86,225	3,221	9,502	725,600
1970	7,488,310	7,551.0	88,390	3,252	9,433	722,500
1971	9,679,645	7,703.1	94,115	3,609	10,442	746,300
1972	9,982,377	7,833.9	99,680	3,625	10,936	792,500
1973	10,903,647	7,938.9	106,845	3,712	12,003	839,200

APPENDIX B

CONVERSION FACTORS

APPENDIX B

CONVERSION FACTORS

Fuel oil[1]	6.10×10^6 Btu/barrel
Natural gas	1,000.0 Btu/cu. ft.
Coal[2]	25.52×10^6 Btu/ton
Electricity	3,412 Btu/kwh
Coke	24.8×10^6 Btu/ton
Crude oil	5.803×10^6 Btu/barrel
Motor gasoline	5.222×10^6 Btu/barrel
Kerosene	5.677×10^6 Btu/barrel
Diesel/light fuel	5.8275×10^6 Btu/barrel
Heavy fuel oil	6.2874×10^6 Btu/barrel
Aviation fuel[3]	5.4145×10^6 Btu/barrel
L.P.G.	4.095×10^6 Btu/barrel
Fuel gas	6.2874×10^6 Btu/barrel
Oxygen[4]	1.706×10^6 Btu/ton
Steam[5]	2.666×10^6 Btu/ton
Coke oven gas	500 Btu/scf[6]
Blast furnace gas	95 Btu/scf[6]

1 U.S. Horsepower-hour = 2,545 Btu

1 Kilocalorie/kilogram = 1.8 Btu/pound

1 Ton = 2,000 pounds

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[1] Four fuel oil types (kerosene, diesel, light and heavy) weighted by actual consumption in Ontario in 1973.

[2] Five coal types (imported bituminous, Canadian bituminous, sub-bituminous, anthracite, lignite) weighted by actual consumption in Ontario in 1973.

[3] Aviation turbo fuel.

[4] Production requirement of 500 kwh/ton (23,700 standard cubic feet/ton.

[5] Production requirement of 1,333 Btu per pound in an 86 per cent efficient boiler.

[6] Standard cubic foot (60°F - 1 atmosphere)

APPENDIX C

STATISTICAL SUMMARY BY INDUSTRY, 1964-1973

APPENDIX C

STATISTICAL SUMMARY BY INDUSTRY, 1964-1973

The following tables list principal statistics and energy statistics by industry group by year, 1964 to 1973.

The price index is from Statistics Canada 62-002 and has been converted to 1971 = 1000. The index reflects the price of the major product of the industry or industry group. Where more than one industry is represented in the group, the weighted average index is used (weighted by the value of shipments).

All other data is from the Census of Manufactures. Monetary values are in current dollars. No comparable data was available for the agricultural sector.

The energy consumption figures are only for purchased fuel and electricity. There is no allowance in these figures for feedstocks or energy used as raw materials. The units of measurement for the energy figures are detailed below:

TONS - Tons of 2000 pounds
KGALS - Thousands of gallons
MCF - Millions of cubic feet
MWH - Millions of watt-hours
GBTU - Billions of British Thermal Units

Thus, K = (Kilo) 10^3
M = (Mega) 10^6
G = (Giga) 10^9

LIST OF INDUSTRY GROUPS INCLUDED IN ONTARIO INDUSTRIAL ENERGY STUDY

(by Report Section)

Section	Industry	SIC[1] Included
3.1	Abrasives	357
3.2	Agriculture	010
3.3	Auto manufacture	323
3.4	Cement	352
3.5	Clay products	351
3.6	Food and beverages	100
3.7	Glass	356
3.8	Industrial chemicals	378
3.9	Iron foundries	294, 325
3.10	Iron and steel	291
3.11	Lime	358
3.12	Mining, smelting	050, 295
3.13	Petroleum refineries	365
3.14	Pulp and paper	271
3.15	Other	150, 160, 170, 180, 230, 240, 250, 260, 279, 280, 299, 300, 310, 329, 330, 354, 359, 369, 379, 390.

[1] Standard Industrial Classification, Statistics Canada.

LIST OF INDUSTRY GROUPS INCLUDED IN ONTARIO INDUSTRIAL ENERGY STUDY

(by SIC[1])

SIC[2]	Report Section	Industry
010	3.2	Agriculture
050	3.12	Mining (including 070 and 080)
100	3.6	Food and beverage industries
150	3.15	Tobacco products industries
160	3.15	Rubber industries
170	3.15	Leather industries
180	3.15	Textile industries
230	3.15	Knitting mills
240	3.15	Clothing industries
250	3.15	Wood industries
260	3.15	Furniture and fixtures
271	3.14	Pulp and paper mills
279	3.15	Paper and allied industries, nes
280	3.15	Printing and publishing
291	3.10	Iron and steel mills
294	3.9	Iron foundries
295	3.12	Smelting and refining
299	3.15	Primary metal industries, nes
300	3.15	Metal fabricating industries
310	3.15	Machinery industries
323	3.3	Motor vehicles manufacturers
325	3.9	Motor vehicle parts manufacturers
329	3.15	Transport equipment, nes
330	3.15	Electrical products industries
351	3.5	Manufacturers of clay products
352	3.4	Cement manufacturers
354	3.15	Concrete products manufacturers
356	3.7	Glass and glass product manufacturers
357	3.1	Abrasives manufacturers
358	3.11	Lime manufacturers
359	3.15	Non-metallic mineral products, nes
365	3.13	Petroleum refineries
369	3.15	Petroleum, coal products, nes
378	3.12	Manufacturers of industrial chemicals
379	3.15	Chemical and chemical products, nes
390	3.15	Miscellaneous industries

[1] Standard Industrial Classification, Statistics Canada.

[2] Defined so as to be consistent with Statistics Canada.

O N T A R I O   I N D U S T R I A L   E N E R G Y   S T U D Y

INDUSTRIAL STATISTICS

S I C - 357 - ABRASIVES MFRS

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	16	16	15	16	16	16	16	17	17	15
EMPLOYEES (#)	1,536	1,703	1,911	1,682	1,496	1,604	1,562	1,387	1,434	1,636
LABOUR COST (000$)	7,976	9,036	10,794	9,871	9,201	10,968	10,647	10,330	12,338	14,944
FUEL COST (000$)	3,559	4,133	4,875	4,215	4,251	5,026	5,092	4,952	5,707	6,781
MATERIALS (000$)	17,547	20,440	23,473	20,462	20,742	23,420	21,927	21,403	25,674	34,271
SHIPMENTS (000$)	44,556	51,147	55,249	50,389	49,654	56,982	53,314	50,793	61,050	74,095
VALUE ADDED (000$)	23,646	26,940	27,493	25,582	25,136	28,696	26,457	24,280	28,681	33,776
PRICE INDEX (1971)	924	925	948	977	982	995	1,012	1,000	1,004	1,048
COAL (000$)	87	75	90	112	103	115	84	0	0	0
GASOLINE (000$)	10	21	19	21	27	22	19	24	22	31
FUEL OIL (000$)	69	72	81	80	62	75	52	45	27	81
NATURAL GAS (000$)	77	90	79	106	100	113	150	227	253	262
L. P. G. (000$)	7	5	8	6	4	3	2	2	3	7
ELECTRICITY (000$)	3,291	3,860	4,579	3,869	3,955	4,692	4,736	4,655	5,401	6,400
OTHER (000$)	9	12	18	21	0	6	0	0	0	0
COAL (TONS)	6,979	7,372	7,032	8,021	7,463	7,910	5,422	0	0	0
GASOLINE (KGALS)	26	54	48	41	63	51	53	61	59	81
FUEL OIL (KGALS)	634	674	733	706	529	626	445	365	141	422
NATURAL GAS (MCF)	82	95	84	112	108	124	183	305	346	324
L. P. G. (KGALS)	21	17	37	30	14	10	9	8	12	24
ELECTRICITY (MWH)	721,082	792,858	918,365	767,471	757,256	748,297	791,558	717,539	858,700	900,419
COAL (GBTU)	178	188	179	204	190	201	138	0	0	0
GASOLINE (GBTU)	3	8	7	6	9	7	7	9	8	12
FUEL OIL (GBTU)	110	117	127	123	92	109	77	63	24	73
NATURAL GAS (GBTU)	82	95	84	112	108	124	183	305	346	324
L. P. G. (GBTU)	2	1	4	3	1	1	1	0	1	2
ELECTRICITY (GBTU)	2,460	2,705	3,133	2,618	2,583	2,553	2,700	2,448	2,929	3,072
TOTAL (GBTU)	2,835	3,114	3,534	3,066	2,983	2,995	3,106	2,825	3,308	3,483
COAL (%)	6.28	6.04	5.07	6.65	6.37	6.71	4.44	0.00	0.00	0.00
GASOLINE (%)	0.11	0.26	0.20	0.20	0.30	0.23	0.23	0.32	0.24	0.34
FUEL OIL (%)	3.88	3.76	3.59	4.01	3.08	3.64	2.48	2.23	0.73	2.10
NATURAL GAS (%)	2.89	3.05	2.38	3.65	3.62	4.14	5.89	10.80	10.46	9.30
L. P. G. (%)	0.07	0.03	0.11	0.10	0.03	0.03	0.03	0.00	0.03	0.06
ELECTRICITY (%)	86.77	86.87	88.65	85.39	86.59	85.24	86.93	86.65	88.54	88.20

K - 10*3
M - 10*6
G - 10*9

ONTARIO INDUSTRIAL ENERGY STUDY

INDUSTRIAL STATISTICS

S I C - 323 - MOTOR VEHICLES MFRS

C-5

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	8	8	8	8	9	10	10	9	9	9
EMPLOYEES (#)	23,412	28,110	27,339	25,006	23,764	25,293	22,217	25,058	26,653	28,887
LABOUR COST (000$)	147,667	198,729	192,372	183,259	208,005	226,238	206,714	241,348	296,378	350,270
FUEL COST (000$)	6,502	7,661	8,228	8,933	10,365	11,624	11,141	12,918	14,154	15,014
MATERIALS (000$)	1,181,129	1,452,468	1,484,110	1,514,171	1,954,744	2,288,818	2,093,644	2,423,298	2,833,701	3,339,156
SHIPMENTS (000$)	1,638,253	2,048,630	2,051,558	2,209,610	2,675,209	3,144,630	2,688,468	3,165,696	3,634,577	4,265,167
VALUE ADDED (000$)	476,600	609,163	577,470	685,631	739,907	831,227	595,685	732,666	802,899	944,677
PRICE INDEX (1971)	951	946	938	938	956	963	976	1,000	1,021	1,013
COAL (000$)	2,177	2,437	2,357	2,171	2,048	2,201	2,219	2,486	2,039	1,652
GASOLINE (000$)	611	788	777	953	1,159	1,424	854	572	607	852
FUEL OIL (000$)	123	229	616	761	860	939	911	1,382	2,073	2,266
NATURAL GAS (000$)	628	726	909	1,304	1,708	1,999	1,943	2,418	2,948	3,035
L. P. G. (000$)	89	104	106	89	77	97	37	51	70	81
ELECTRICITY (000$)	2,739	3,231	3,438	3,654	4,413	4,963	5,177	6,009	6,417	7,129
OTHER (000$)	135	146	24	0	0	0	0	0	0	0
COAL (TONS)	199,243	222,604	211,161	198,398	170,785	179,335	159,809	146,384	105,854	83,439
GASOLINE (KGALS)	2,341	3,202	3,442	3,744	3,891	4,524	2,665	1,813	2,002	2,496
FUEL OIL (KGALS)	1,089	2,211	7,470	9,224	11,581	11,694	11,376	13,365	16,598	18,053
NATURAL GAS (MCF)	824	968	1,092	1,701	2,389	2,786	2,707	3,509	4,467	4,378
L. P. G. (KGALS)	890	1,044	1,171	773	471	687	288	396	607	649
ELECTRICITY (MWH)	369,778	445,434	474,000	493,564	584,695	644,755	598,104	670,939	700,220	724,077
COAL (GBTU)	5,084	5,680	5,388	5,063	4,358	4,576	4,078	3,735	2,701	2,129
GASOLINE (GBTU)	349	477	513	558	580	674	397	270	298	372
FUEL OIL (GBTU)	189	385	1,302	1,607	2,018	2,038	1,982	2,329	2,893	3,146
NATURAL GAS (GBTU)	824	968	1,092	1,761	2,389	2,786	2,707	3,509	4,467	4,378
L. P. G. (GBTU)	104	122	137	90	55	80	33	46	71	75
ELECTRICITY (GBTU)	1,261	1,519	1,617	1,684	1,994	2,199	2,040	2,289	2,389	2,470
TOTAL (GBTU)	7,811	9,151	10,049	10,763	11,394	12,353	11,237	12,178	12,819	12,570
COAL (%)	65.09	62.07	53.62	47.30	38.25	37.04	36.29	30.67	21.07	16.94
GASOLINE (%)	4.47	5.21	5.10	5.21	5.09	5.46	3.53	2.22	2.32	2.96
FUEL OIL (%)	2.42	4.21	12.96	15.01	17.71	16.50	17.64	19.12	22.57	25.03
NATURAL GAS (%)	10.55	10.58	10.87	15.89	20.97	22.55	24.09	28.81	34.85	34.83
L. P. G. (%)	1.33	1.33	1.36	0.84	0.48	0.65	0.29	0.38	0.55	0.60
ELECTRICITY (%)	16.14	16.60	16.09	15.73	17.50	17.80	18.15	18.80	18.64	19.65

K - 10*3
M - 10*6
G - 10*9

C-6

ONTARIO INDUSTRIAL ENERGY STUDY

INDUSTRIAL STATISTICS

S I C - 352 - CEMENT MFRS

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	6	6	6	5	5	6	6	6	6	7
EMPLOYEES (#)	806	853	880	751	751	825	822	856	929	909
LABOUR COST (000$)	4,508	5,421	5,773	5,080	5,472	6,410	6,836	8,152	9,088	9,989
FUEL COST (000$)	7,741	9,329	9,430	8,587	8,674	9,368	10,130	11,667	13,123	15,650
MATERIALS (000$)	5,152	5,950	6,320	6,046	6,184	7,715	9,363	10,987	12,446	14,230
SHIPMENTS (000$)	48,409	51,117	53,750	47,682	54,658	57,673	61,677	71,292	80,591	93,414
VALUE ADDED (000$)	34,872	36,327	38,625	34,082	39,554	41,324	42,604	48,184	56,035	62,002
PRICE INDEX (1971)	792	803	820	858	893	929	965	1,000	1,064	1,078
COAL (000$)	4,196	5,820	6,081	5,322	4,059	2,972	2,682	2,167	1,962	2,294
GASOLINE (000$)	24	30	26	21	24	31	22	23	26	22
FUEL OIL (000$)	1,431	1,145	869	802	1,305	1,230	1,724	2,536	3,438	4,015
NATURAL GAS (000$)	166	143	193	356	987	2,418	2,851	3,571	4,102	4,883
L. P. G. (000$)	1	1	1	2	2	6	9	6	3	5
ELECTRICITY (000$)	1,923	2,189	2,260	2,083	2,287	2,684	2,843	3,361	3,591	4,431
OTHER (000$)	0	0	0	0	0	27	0	0	0	0
COAL (TONS)	420,164	567,661	580,511	481,997	365,889	264,185	222,621	151,812	138,210	158,003
GASOLINE (KGALS)	89	94	77	66	63	80	56	58	66	48
FUEL OIL (KGALS)	21,038	16,623	12,096	12,066	17,021	16,188	23,981	33,739	41,656	40,834
NATURAL GAS (MCF)	500	436	508	938	2,466	5,890	6,854	7,969	8,910	9,433
L. P. G. (KGALS)	2	5	4	6	7	21	35	26	12	15
ELECTRICITY (MWH)	328,479	375,215	400,475	362,890	378,413	402,719	406,094	445,255	456,549	509,199
COAL (GBTU)	10,722	14,486	14,814	12,300	9,337	6,742	5,681	3,874	3,527	4,032
GASOLINE (GBTU)	13	14	11	9	9	11	8	8	9	7
FUEL OIL (GBTU)	3,666	2,897	2,108	2,103	2,966	2,821	4,179	5,880	7,260	7,117
NATURAL GAS (GBTU)	500	436	508	938	2,466	5,890	6,854	7,969	8,910	9,433
L. P. G. (GBTU)	0	0	0	0	0	2	4	3	1	1
ELECTRICITY (GBTU)	1,120	1,280	1,366	1,238	1,291	1,374	1,385	1,519	1,557	1,737
TOTAL (GBTU)	16,021	19,113	18,807	16,588	16,069	16,840	18,111	19,253	21,264	22,327
COAL (%)	66.92	75.79	78.77	74.15	58.11	40.04	31.37	20.12	16.59	18.06
GASOLINE (%)	0.08	0.07	0.06	0.05	0.06	0.07	0.04	0.04	0.04	0.03
FUEL OIL (%)	22.88	15.16	11.21	12.68	18.46	16.75	23.07	30.54	34.14	31.88
NATURAL GAS (%)	3.12	2.28	2.70	5.65	15.35	34.98	37.84	41.39	41.90	42.25
L. P. G. (%)	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.00	0.00
ELECTRICITY (%)	6.99	6.70	7.26	7.46	8.03	8.16	7.65	7.89	7.32	7.78

K - 10*3
M - 10*6
G - 10*9

O N T A R I O   I N D U S T R I A L   E N E R G Y   S T U D Y

INDUSTRIAL STATISTICS

S I C - 351 - MFRS OF CLAY PRODUCTS

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	71	68	70	68	67	69	68	66	62	58
EMPLOYEES (#)	2,428	2,446	2,618	2,542	2,512	2,560	2,374	2,159	2,112	2,379
LABOUR COST (000$)	10,187	10,941	12,505	12,691	13,306	14,533	14,514	13,673	15,183	13,864
FUEL COST (000$)	4,005	4,102	4,336	4,342	4,706	4,995	4,410	4,046	4,570	4,951
MATERIALS (000$)	9,179	9,890	10,799	11,358	11,076	12,275	12,957	12,462	13,162	17,161
SHIPMENTS (000$)	38,836	42,516	43,440	45,818	48,617	50,008	48,013	52,552	54,173	57,710
VALUE ADDED (000$)	25,189	28,685	29,427	30,164	32,229	34,030	32,851	33,963	36,515	45,189
PRICE INDEX (1971)	825	832	854	875	904	949	972	1,000	1,043	1,125
COAL (000$)	651	548	509	470	461	249	50	2	2	429
GASOLINE (000$)	226	232	257	274	265	242	225	218	187	206
FUEL OIL (000$)	287	291	289	304	346	342	314	279	313	361
NATURAL GAS (000$)	2,119	2,267	2,509	2,512	2,530	2,969	2,949	2,696	3,091	2,864
L. P. G. (000$)	16	61	27	27	87	27	16	17	15	14
ELECTRICITY (000$)	654	662	697	709	739	828	855	833	962	1,077
OTHER (000$)	52	41	49	46	278	337	0	0	0	0
COAL (TONS)	52,373	45,722	36,927	31,708	30,448	15,550	2,526	85	96	18,063
GASOLINE (KGALS)	672	672	790	725	678	597	554	504	434	477
FUEL OIL (KGALS)	2,342	2,370	2,416	2,413	2,564	2,710	2,037	1,732	1,770	1,617
NATURAL GAS (MCF)	3,886	3,768	4,261	4,120	4,275	4,873	4,732	4,295	4,472	4,060
L. P. G. (KGALS)	79	274	114	118	249	128	74	78	67	54
ELECTRICITY (MWH)	57,849	62,944	68,966	68,706	60,955	74,556	76,018	69,617	80,260	67,324
COAL (GBTU)	1,336	1,166	942	809	777	396	64	2	2	460
GASOLINE (GBTU)	100	100	117	108	101	89	82	75	64	71
FUEL OIL (GBTU)	408	413	421	420	446	472	355	301	308	281
NATURAL GAS (GBTU)	3,886	3,768	4,261	4,120	4,275	4,873	4,732	4,295	4,472	4,060
L. P. G. (GBTU)	9	32	13	13	29	14	8	9	7	6
ELECTRICITY (GBTU)	197	214	235	234	207	254	259	237	273	229
TOTAL (GBTU)	5,936	5,693	5,989	5,704	5,835	6,098	5,500	4,919	5,126	5,107
COAL (%)	22.51	20.48	15.73	14.18	13.32	6.49	1.16	0.04	0.04	9.01
GASOLINE (%)	1.68	1.76	1.95	1.89	1.73	1.46	1.49	1.52	1.25	1.39
FUEL OIL (%)	6.87	7.25	7.03	7.36	7.64	7.74	6.45	6.12	6.01	5.50
NATURAL GAS (%)	65.46	66.19	71.15	72.23	73.26	79.91	86.04	87.31	87.24	79.50
L. P. G. (%)	0.15	0.56	0.22	0.23	0.50	0.23	0.15	0.18	0.14	0.12
ELECTRICITY (%)	3.32	3.76	3.92	4.10	3.55	4.17	4.71	4.82	5.33	4.48

K - 10*3
M - 10*6
G - 10*9

ONTARIO INDUSTRIAL ENERGY STUDY

INDUSTRIAL STATISTICS

SIC - 100 - FOOD AND BEVERAGE INDUSTRIES

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	2,583	2,460	2,386	2,307	2,148	2,049	1,916	1,829	1,731	1,673
EMPLOYEES (#)	51,540	52,830	54,598	54,751	52,988	52,139	52,608	52,087	53,243	61,913
LABOUR COST (000$)	203,628	220,281	238,853	256,651	268,503	288,546	313,822	341,285	374,273	413,040
FUEL COST (000$)	35,073	37,506	39,071	39,799	40,262	41,085	40,952	44,397	47,353	50,051
MATERIALS (000$)	1,601,280	1,706,595	1,853,615	1,927,240	1,926,689	2,056,770	2,195,057	2,283,027	2,576,392	3,175,020
SHIPMENTS (000$)	2,543,314	2,701,290	2,927,978	3,064,451	3,118,031	3,319,688	3,485,350	3,693,712	4,142,471	4,930,235
VALUE ADDED (000$)	923,606	978,656	1,059,079	1,114,504	1,165,291	1,241,951	1,274,852	1,394,438	1,543,030	1,754,746
PRICE INDEX (1971)	836	844	889	896	909	954	978	1,000	1,079	1,291
COAL (000$)	3,274	2,871	2,565	2,189	1,788	1,309	1,328	914	111	96
GASOLINE (000$)	8,758	9,575	10,168	10,636	10,798	11,432	11,255	11,004	10,710	10,638
FUEL OIL (000$)	6,072	7,433	8,100	9,013	9,175	8,812	8,191	9,148	9,961	9,629
NATURAL GAS (000$)	4,855	5,007	5,292	5,430	5,631	6,192	7,363	9,147	11,099	12,557
L. P. G. (000$)	277	260	263	316	387	473	402	374	304	352
ELECTRICITY (000$)	8,533	9,242	9,655	10,187	10,634	11,331	11,978	13,274	14,625	16,182
OTHER (000$)	3,306	3,120	3,028	2,029	1,850	1,537	435	536	542	596
COAL (TONS)	271,947	238,425	212,099	178,449	141,216	102,238	93,152	51,305	4,893	3,548
GASOLINE (KGALS)	25,624	27,525	28,509	29,064	28,400	29,568	28,690	27,544	26,004	23,665
FUEL OIL (KGALS)	61,530	76,234	81,828	92,266	93,142	88,689	79,100	74,872	68,433	58,628
NATURAL GAS (MCF)	8,638	8,694	9,661	9,120	9,927	10,520	12,620	15,020	17,784	19,563
L. P. G. (KGALS)	1,034	1,198	1,141	1,369	1,715	2,025	1,739	1,771	1,497	1,644
ELECTRICITY (MWH)	828,285	927,117	962,207	1,025,532	1,036,461	1,149,636	1,199,099	1,265,151	1,285,379	1,330,000
COAL (GBTU)	6,940	6,084	5,412	4,554	3,603	2,609	2,377	1,309	124	90
GASOLINE (GBTU)	3,823	4,106	4,253	4,336	4,237	4,411	4,280	4,109	3,879	3,530
FUEL OIL (GBTU)	10,724	13,287	14,262	16,081	16,234	15,458	13,787	13,050	11,927	10,218
NATURAL GAS (GBTU)	8,638	8,694	9,661	9,120	9,927	10,520	12,620	15,020	17,784	19,563
L. P. G. (GBTU)	120	139	133	160	200	236	203	207	175	192
ELECTRICITY (GBTU)	2,826	3,163	3,283	3,499	3,536	3,922	4,091	4,316	4,385	4,537
TOTAL (GBTU)	33,071	35,473	37,004	37,750	37,737	37,156	37,358	38,011	38,274	38,130
COAL (%)	20.99	17.15	14.63	12.06	9.55	7.02	6.36	3.44	0.32	0.24
GASOLINE (%)	11.56	11.58	11.49	11.49	11.23	11.87	11.46	10.81	10.13	9.26
FUEL OIL (%)	32.43	37.46	38.54	42.60	43.02	41.60	36.91	34.33	31.16	26.80
NATURAL GAS (%)	26.12	24.51	26.11	24.16	26.31	28.31	33.78	39.51	46.46	51.31
L. P. G. (%)	0.36	0.39	0.36	0.42	0.53	0.64	0.54	0.54	0.46	0.50
ELECTRICITY (%)	8.55	8.92	8.87	9.27	8.37	10.56	10.95	11.35	11.46	11.90

K - 10*3
M - 10*6
G - 10*9

ONTARIO INDUSTRIAL ENERGY STUDY

INDUSTRIAL STATISTICS

SIC - 356 - GLASS & GLASS PROD MFRS

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	53	56	57	58	55	56	50	51	50	48
EMPLOYEES (#)	4,537	5,151	5,271	5,486	5,754	5,661	5,308	5,760	5,798	6,463
LABOUR COST (000$)	21,816	26,009	28,286	31,918	35,963	40,541	37,196	42,630	47,723	56,812
FUEL COST (000$)	3,239	3,640	3,850	5,166	6,396	6,900	6,531	8,041	8,927	9,967
MATERIALS (000$)	38,124	46,963	49,855	52,484	58,764	66,622	62,090	73,096	77,648	95,275
SHIPMENTS (000$)	90,656	108,204	114,731	123,796	152,842	168,184	164,280	199,704	218,023	267,864
VALUE ADDED (000$)	50,348	58,519	61,340	69,855	90,793	98,601	95,503	119,786	134,233	164,976
PRICE INDEX (1971)	801	806	835	855	874	913	960	1,000	1,070	1,114
COAL (000$)	35	38	27	13	13	12	16	8	5	0
GASOLINE (000$)	37	58	60	61	110	118	71	95	107	117
FUEL OIL (000$)	1,056	1,118	1,069	911	656	377	140	164	181	163
NATURAL GAS (000$)	1,085	1,265	1,496	2,715	3,875	4,471	4,255	5,427	5,988	6,662
L. P. G. (000$)	8	12	12	29	30	38	33	51	55	62
ELECTRICITY (000$)	960	1,115	1,143	1,414	1,689	1,854	2,016	2,279	2,592	2,962
OTHER (000$)	59	34	43	22	21	30	0	16	0	0
COAL (TONS)	3,054	3,087	2,110	975	970	924	1,143	410	238	0
GASOLINE (KGALS)	123	156	163	162	303	339	196	257	254	252
FUEL OIL (KGALS)	12,984	13,308	12,275	10,228	7,112	4,102	1,485	1,169	1,264	908
NATURAL GAS (MCF)	1,843	2,156	2,591	4,789	6,846	8,000	7,627	9,742	10,251	10,891
L. P. G. (KGALS)	38	54	54	119	151	186	162	185	207	205
ELECTRICITY (MWH)	138,332	163,308	161,373	196,949	228,632	241,189	246,295	269,303	292,530	310,826
COAL (GBTU)	77	78	53	24	24	23	29	10	6	0
GASOLINE (GBTU)	18	23	24	24	45	50	29	38	37	37
FUEL OIL (GBTU)	2,263	2,319	2,139	1,782	1,239	714	258	203	220	158
NATURAL GAS (GBTU)	1,843	2,156	2,591	4,789	6,846	8,000	7,627	9,742	10,251	10,891
L. P. G. (GBTU)	4	6	6	13	17	21	18	21	24	23
ELECTRICITY (GBTU)	471	557	550	671	780	822	840	918	998	1,060
TOTAL (GBTU)	4,676	5,139	5,363	7,303	8,951	9,630	8,801	10,932	11,536	12,169
COAL (%)	1.65	1.52	0.99	0.33	0.27	0.24	0.33	0.09	0.05	0.00
GASOLINE (%)	0.38	0.45	0.45	0.33	0.50	0.52	0.33	0.35	0.32	0.30
FUEL OIL (%)	48.40	45.13	39.88	24.40	13.84	7.41	2.93	1.86	1.91	1.30
NATURAL GAS (%)	39.41	41.95	48.31	65.58	76.48	83.07	86.66	89.11	88.86	89.50
L. P. G. (%)	0.09	0.12	0.11	0.18	0.19	0.22	0.20	0.19	0.21	0.19
ELECTRICITY (%)	10.07	10.84	10.26	9.19	8.71	8.54	9.54	8.40	8.65	8.71

K - 10*3
M - 10*6
G - 10*9

ONTARIO INDUSTRIAL ENERGY STUDY

INDUSTRIAL STATISTICS

SIC - 378 - MFRS OF INDL CHEMICALS

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	57	58	60	60	62	62	62	64	62	62
EMPLOYEES (#)	6,763	6,925	7,295	7,468	7,623	7,841	7,894	7,477	6,954	7,419
LABOUR COST (000$)	39,271	41,859	47,641	51,667	57,025	63,793	71,328	72,359	73,880	32,952
FUEL COST (000$)	32,419	35,466	41,081	41,232	43,932	47,918	51,962	53,289	57,067	71,932
MATERIALS (000$)	150,962	173,049	191,486	197,317	207,214	226,683	233,587	248,525	268,983	320,290
SHIPMENTS (000$)	376,543	423,849	478,401	482,753	526,190	561,373	566,261	588,647	605,639	753,554
VALUE ADDED (000$)	194,673	217,139	243,958	252,569	271,307	288,246	286,781	286,526	281,355	366,888
PRICE INDEX (1971)	1,021	1,001	997	1,009	1,009	1,006	993	1,000	1,024	1,085
COAL (000$)	8,722	9,948	10,513	9,926	8,020	6,656	2,856	631	183	253
GASOLINE (000$)	260	301	361	397	407	422	435	449	416	464
FUEL OIL (000$)	1,283	1,718	2,513	3,913	3,574	3,675	2,728	5,732	9,225	14,833
NATURAL GAS (000$)	2,191	2,176	3,568	3,631	5,667	8,071	14,660	15,101	16,751	20,734
L. P. G. (000$)	545	241	166	165	1,167	1,066	881	1,525	4,188	267
ELECTRICITY (000$)	13,317	14,893	17,539	17,421	19,193	21,190	23,719	24,677	22,485	25,504
OTHER (000$)	6,101	6,188	6,422	5,778	5,904	6,837	6,684	5,174	3,815	9,877
COAL (TONS)	1,086,975	1,170,636	1,231,778	1,102,265	860,800	685,263	235,163	50,618	14,405	18,174
GASOLINE (KGALS)	802	869	923	1,021	1,044	1,062	1,015	1,043	913	966
FUEL OIL (KGALS)	14,595	19,689	29,660	43,223	46,215	48,369	32,210	63,823	105,590	162,327
NATURAL GAS (MCF)	4,630	4,137	7,174	7,077	11,046	17,023	31,944	32,635	34,811	40,192
L. P. G. (KGALS)	2,484	919	550	552	5,225	4,758	3,953	6,919	16,739	1,224
ELECTRICITY (MWH)	2,327,017	2,497,342	3,031,227	3,124,223	3,479,945	3,546,991	3,771,110	3,618,125	3,219,553	3,062,239
COAL (GBTU)	27,739	29,874	31,434	28,129	21,967	17,487	6,001	1,291	367	463
GASOLINE (GBTU)	119	129	137	152	155	158	151	155	136	144
FUEL OIL (GBTU)	2,543	3,431	5,169	7,533	8,055	8,430	5,614	11,124	18,404	28,293
NATURAL GAS (GBTU)	4,630	4,137	7,174	7,077	11,046	17,023	31,944	32,635	34,811	40,192
L. P. G. (GBTU)	290	107	64	64	611	556	462	809	1,958	143
ELECTRICITY (GBTU)	7,939	8,520	10,342	10,659	11,873	12,102	12,867	12,345	10,985	10,448
TOTAL (GBTU)	43,260	46,198	54,320	53,614	53,707	55,756	57,039	58,359	66,661	79,683
COAL (%)	64.12	64.67	57.87	52.47	40.90	31.36	10.52	2.21	0.55	0.58
GASOLINE (%)	0.28	0.28	0.25	0.28	0.29	0.28	0.26	0.27	0.20	0.18
FUEL OIL (%)	5.88	7.43	9.52	14.05	15.00	15.12	9.84	19.06	27.61	35.51
NATURAL GAS (%)	10.70	8.95	13.21	13.20	20.57	30.53	56.00	55.92	52.22	50.44
L. P. G. (%)	0.67	0.23	0.12	0.12	1.14	1.00	0.81	1.39	2.94	0.18
ELECTRICITY (%)	18.35	18.44	19.04	19.88	22.11	21.71	22.56	21.15	16.48	13.11

K - 10*3
M - 10*6
G - 10*9

ONTARIO INDUSTRIAL ENERGY STUDY

INDUSTRIAL STATISTICS

SIC - - FOUNDRIES (INCL. AUTO PARTS)

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	184	188	203	205	202	198	196	213	224	232
EMPLOYEES (#)	28,934	32,323	35,459	34,711	37,765	39,997	35,950	40,384	42,446	48,801
LABOUR COST (000$)	152,677	186,200	198,301	199,601	250,724	283,822	266,851	341,558	384,531	483,904
FUEL COST (000$)	9,077	12,094	14,338	15,596	17,880	17,806	18,822	22,799	25,976	30,031
MATERIALS (000$)	385,390	460,883	531,089	544,882	709,646	789,064	760,538	940,912	1,072,113	1,324,845
SHIPMENTS (000$)	706,351	859,225	986,764	1,027,362	1,308,942	1,464,118	1,393,671	1,777,164	2,028,159	2,451,033
VALUE ADDED (000$)	326,629	384,780	452,337	470,707	581,466	685,337	613,721	812,338	943,157	1,118,376
PRICE INDEX (1971)	884	897	906	924	939	960	984	1,000	1,020	1,061
COAL (000$)	2,104	2,088	2,281	2,356	2,442	1,007	1,008	1,042	909	510
GASOLINE (000$)	381	402	485	526	656	724	723	783	901	992
FUEL OIL (000$)	977	1,165	1,235	1,341	1,391	1,386	1,289	1,645	2,155	2,340
NATURAL GAS (000$)	1,757	2,697	3,467	3,546	4,170	4,275	4,353	5,209	5,862	6,900
L. P. G. (000$)	79	72	162	151	165	176	177	152	227	283
ELECTRICITY (000$)	3,622	5,083	5,999	6,871	8,170	9,234	9,919	12,605	14,482	17,632
OTHER (000$)	156	538	708	805	888	1,004	1,350	1,364	1,441	1,373
COAL (TONS)	196,618	191,215	205,167	207,223	209,224	69,871	59,714	51,022	39,534	23,617
GASOLINE (KGALS)	1,162	1,280	1,483	1,566	1,874	2,179	2,243	2,477	2,708	2,929
FUEL OIL (KGALS)	9,314	11,047	12,067	12,689	13,711	13,786	18,125	13,738	15,200	13,545
NATURAL GAS (MCF)	2,312	3,605	5,014	4,771	5,796	6,040	6,023	7,245	8,198	9,414
L. P. G. (KGALS)	338	359	852	720	710	752	829	764	1,006	1,370
ELECTRICITY (MWH)	384,248	549,470	624,792	741,775	858,379	964,068	951,220	1,172,907	1,291,472	1,541,749
COAL (GBTU)	5,017	4,879	5,235	5,288	5,339	1,783	1,523	1,302	1,008	602
GASOLINE (GBTU)	173	190	221	233	279	325	334	369	404	437
FUEL OIL (GBTU)	1,623	1,925	2,103	2,211	2,389	2,402	3,159	2,394	2,649	2,360
NATURAL GAS (GBTU)	2,312	3,605	5,014	4,771	5,796	6,040	6,023	7,245	8,198	9,414
L. P. G. (GBTU)	39	42	99	84	83	87	96	89	117	160
ELECTRICITY (GBTU)	1,311	1,874	2,131	2,530	2,928	3,289	3,245	4,001	4,406	5,260
TOTAL (GBTU)	10,475	12,515	14,803	15,117	16,814	13,926	14,380	15,400	16,782	18,233
COAL (%)	47.89	38.99	35.36	34.98	31.75	12.80	10.59	8.45	6.01	3.30
GASOLINE (%)	1.65	1.52	1.49	1.54	1.66	2.33	2.32	2.40	2.41	2.40
FUEL OIL (%)	15.49	15.38	14.21	14.63	14.21	17.25	21.97	15.55	15.78	12.94
NATURAL GAS (%)	22.07	28.81	33.87	31.56	34.47	43.37	41.88	47.05	48.85	51.63
L. P. G. (%)	0.37	0.34	0.67	0.56	0.49	0.62	0.67	0.58	0.70	0.88
ELECTRICITY (%)	12.52	14.97	14.40	16.74	17.41	23.62	22.57	25.98	26.25	28.85

K - 10*3
M - 10*6
G - 10*9

O N T A R I O   I N D U S T R I A L   E N E R G Y   S T U D Y

INDUSTRIAL STATISTICS

S I C - 291 - IRON AND STEEL MILLS

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	18	16	16	17	17	17	17	18	17	17
EMPLOYEES (#)	26,496	28,155	29,302	28,398	28,875	25,595	29,865	29,746	29,974	31,781
LABOUR COST (000$)	157,514	173,672	187,043	190,537	205,591	194,848	247,071	266,710	297,624	350,539
FUEL COST (000$)	31,594	36,843	38,702	39,589	39,797	38,627	46,152	49,356	53,711	62,724
MATERIALS (000$)	413,233	448,168	443,087	444,789	491,673	475,073	612,164	620,429	686,850	826,125
SHIPMENTS (000$)	914,056	1,012,278	1,017,974	1,010,257	1,110,643	1,074,887	1,317,165	1,394,485	1,517,837	1,849,298
VALUE ADDED (000$)	472,132	550,103	543,044	528,871	580,750	567,137	690,768	736,529	778,259	969,801
PRICE INDEX (1971)	842	859	862	876	873	904	954	1,000	1,033	1,107
COAL (000$)	1,445	1,874	2,270	1,590	1,572	1,215	389	176	0	0
GASOLINE (000$)	219	251	257	239	260	257	286	272	301	312
FUEL OIL (000$)	13,307	14,845	14,544	14,316	11,704	9,613	11,490	12,200	10,171	7,970
NATURAL GAS (000$)	4,105	5,140	5,742	6,734	7,830	8,259	10,822	13,033	15,432	18,261
L. P. G. (000$)	20	18	17	10	10	9	9	51	66	257
ELECTRICITY (000$)	12,498	14,715	15,870	16,615	18,172	19,082	22,972	23,336	27,250	32,785
OTHER (000$)	0	0	0	85	249	194	183	287	491	3,139
COAL (TONS)	136,016	180,718	208,738	145,571	134,734	105,072	33,331	15,834	0	0
GASOLINE (KGALS)	805	905	912	902	957	855	934	879	949	987
FUEL OIL (KGALS)	152,999	167,089	163,704	168,310	131,367	110,252	126,557	97,508	85,921	60,529
NATURAL GAS (MCF)	8,314	10,576	12,035	12,679	15,463	16,518	21,615	26,296	30,893	34,933
L. P. G. (KGALS)	96	88	89	46	41	38	42	414	487	1,009
ELECTRICITY (MWH)	2,169,468	2,463,624	2,648,304	2,634,441	2,853,446	2,863,354	3,167,497	3,252,242	3,461,652	3,686,022
COAL (GBTU)	3,471	4,611	5,326	3,714	3,438	2,681	850	404	0	0
GASOLINE (GBTU)	120	135	136	134	142	127	139	131	141	147
FUEL OIL (GBTU)	26,667	29,123	28,533	29,336	22,887	19,216	22,058	16,995	14,976	10,550
NATURAL GAS (GBTU)	8,314	10,576	12,035	12,679	15,463	16,518	21,615	26,296	30,893	34,933
L. P. G. (GBTU)	11	10	10	5	4	4	4	48	56	118
ELECTRICITY (GBTU)	7,402	8,405	9,036	8,988	9,735	9,769	10,807	11,096	11,811	12,576
TOTAL (GBTU)	45,985	52,860	55,076	54,856	51,679	48,315	55,473	54,970	57,877	58,324
COAL (%)	7.55	8.72	9.67	6.77	6.65	5.55	1.53	0.73	0.00	0.00
GASOLINE (%)	0.26	0.26	0.25	0.24	0.27	0.26	0.25	0.24	0.24	0.25
FUEL OIL (%)	57.99	55.09	51.81	53.48	44.31	39.77	39.76	30.92	25.88	18.09
NATURAL GAS (%)	18.08	20.01	21.85	23.11	29.92	34.19	38.96	47.84	53.38	59.89
L. P. G. (%)	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.09	0.10	0.20
ELECTRICITY (%)	16.10	15.90	16.41	16.38	18.84	20.22	19.48	20.19	20.41	21.56

K - 10*3
M - 10*6
G - 10*9

O N T A R I O   I N D U S T R I A L   E N E R G Y   S T U D Y

INDUSTRIAL STATISTICS

S I C - 358 - LIME MFRS

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	8	6	5	5	5	5	7	6	6	6
EMPLOYEES (#)	318	331	326	301	298	304	280	285	294	302
LABOUR COST (000$)	1,610	1,776	1,763	1,733	1,825	1,902	1,804	2,041	2,333	2,612
FUEL COST (000$)	1,585	1,830	1,739	1,620	1,742	1,813	3,002	3,500	4,169	4,651
MATERIALS (000$)	1,285	1,516	1,462	1,349	1,531	1,430	1,709	2,687	2,746	2,555
SHIPMENTS (000$)	8,571	9,268	7,927	6,997	7,838	8,413	10,883	12,729	13,484	15,193
VALUE ADDED (000$)	5,684	5,920	4,706	4,005	4,712	5,223	6,234	6,598	6,592	8,112
PRICE INDEX (1971)	767	781	801	824	865	899	933	1,000	1,080	1,171
COAL (000$)	1,043	1,148	1,155	1,058	979	1,001	1,248	631	625	689
GASOLINE (000$)	17	13	16	19	13	15	13	34	33	52
FUEL OIL (000$)	57	55	40	54	61	68	769	1,031	1,350	1,164
NATURAL GAS (000$)	304	430	366	332	528	565	728	1,490	1,804	2,326
L. P. G. (000$)	0	0	0	0	0	0	0	0	0	0
ELECTRICITY (000$)	156	180	161	156	159	163	243	315	358	418
OTHER (000$)	8	5	3	2	2	1	1	0	0	2
COAL (TONS)	84,819	90,700	86,326	79,826	71,190	71,932	70,082	31,364	28,597	30,041
GASOLINE (KGALS)	68	57	70	85	44	48	43	105	81	116
FUEL OIL (KGALS)	516	470	352	477	541	625	8,995	9,632	11,342	5,636
NATURAL GAS (MCF)	502	718	603	538	868	930	1,207	2,412	3,615	4,061
L. P. G. (KGALS)	0	0	0	0	0	0	4	2	2	1
ELECTRICITY (MWH)	19,098	22,967	21,229	21,033	21,291	21,001	29,984	35,329	41,305	39,307
COAL (GBTU)	2,164	2,314	2,203	2,037	1,816	1,835	1,788	800	729	766
GASOLINE (GBTU)	10	8	10	12	6	7	6	15	12	17
FUEL OIL (GBTU)	89	81	61	83	94	108	1,567	1,678	1,976	982
NATURAL GAS (GBTU)	592	718	603	538	868	930	1,207	2,412	3,615	4,061
L. P. G. (GBTU)	0	0	0	0	0	0	0	0	0	0
ELECTRICITY (GBTU)	65	78	72	71	72	71	102	120	140	134
TOTAL (GBTU)	2,830	3,199	2,949	2,741	2,856	2,951	4,670	5,025	6,472	5,960
COAL (%)	76.47	72.34	74.70	74.32	63.59	62.18	38.29	15.92	11.26	12.85
GASOLINE (%)	0.35	0.25	0.34	0.44	0.21	0.24	0.13	0.30	0.19	0.29
FUEL OIL (%)	3.14	2.53	2.07	3.03	3.29	3.66	33.55	33.39	30.53	16.48
NATURAL GAS (%)	17.74	22.44	20.45	19.63	30.39	31.51	25.85	48.00	55.86	68.14
L. P. G. (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ELECTRICITY (%)	2.30	2.44	2.44	2.59	2.52	2.41	2.18	2.39	2.16	2.25

K - 10*3
M - 10*6
G - 10*9

ONTARIO INDUSTRIAL ENERGY STUDY

INDUSTRIAL STATISTICS

S I C - - MINING, SMELTING & REFINING

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	372	346	334	288	297	275	259	250	237	219
EMPLOYEES (#)	34,306	35,901	35,440	35,155	35,727	29,959	35,991	35,922	32,021	30,361
LABOUR COST (000$)	170,144	188,080	191,704	222,630	242,354	203,800	282,975	301,022	289,991	295,639
FUEL COST (000$)	38,354	43,204	42,788	47,316	54,804	50,542	64,898	74,385	70,122	76,522
MATERIALS (000$)	263,527	301,991	313,312	391,639	434,387	427,794	572,139	588,091	506,527	507,279
SHIPMENTS (000$)	907,180	982,506	944,027	1,187,278	1,323,819	1,221,562	1,611,400	1,530,367	1,507,143	2,036,417
VALUE ADDED (000$)	605,299	637,312	587,926	748,386	834,627	743,227	974,363	867,890	930,493	1,322,615
PRICE INDEX (1971)	774	814	848	883	910	958	1,030	1,000	1,014	1,178
COAL (000$)	7,705	10,056	9,769	11,227	11,513	8,212	12,977	16,286	11,035	9,158
GASOLINE (000$)	1,213	1,534	1,621	1,671	1,743	1,627	1,722	1,810	2,037	1,830
FUEL OIL (000$)	4,517	4,813	4,932	4,631	6,523	6,016	6,474	8,540	10,038	13,212
NATURAL GAS (000$)	5,247	5,959	6,167	8,074	9,847	9,469	11,762	12,481	12,255	14,478
L. P. G. (000$)	46	199	436	93	122	168	329	370	675	627
ELECTRICITY (000$)	19,035	20,229	19,329	21,301	24,698	24,755	31,590	34,882	34,068	40,217
OTHER (000$)	592	411	531	317	355	295	43	19	14	2
COAL (TONS)	550,270	641,247	597,371	662,625	702,906	493,793	611,544	728,162	572,986	394,426
GASOLINE (KGALS)	3,552	4,375	4,755	4,790	4,943	4,435	4,836	4,676	5,019	4,395
FUEL OIL (KGALS)	36,385	38,498	38,917	36,994	51,981	47,242	48,821	58,447	58,979	54,054
NATURAL GAS (MCF)	11,911	13,090	13,345	17,600	21,523	19,942	24,407	25,744	25,426	28,597
L. P. G. (KGALS)	156	575	1,532	335	457	900	1,261	2,206	3,105	3,494
ELECTRICITY (MWH)	3,119,553	3,397,820	3,350,746	3,893,238	4,361,503	3,972,555	4,835,726	5,000,143	4,790,942	5,187,907
COAL (GBTU)	14,042	16,364	15,244	16,910	17,938	12,601	15,606	18,582	14,622	10,065
GASOLINE (GBTU)	529	652	709	714	737	661	721	697	748	655
FUEL OIL (GBTU)	6,341	6,710	6,783	6,448	9,060	8,234	8,509	10,187	10,280	9,421
NATURAL GAS (GBTU)	11,911	13,090	13,345	17,600	21,523	19,942	24,407	25,744	25,426	28,597
L. P. G. (GBTU)	18	67	179	39	53	105	147	258	363	408
ELECTRICITY (GBTU)	10,643	11,593	11,432	13,283	14,881	13,554	16,499	17,060	16,346	17,701
TOTAL (GBTU)	43,484	48,476	47,692	54,994	64,192	55,097	65,889	72,528	67,785	66,847
COAL (%)	32.29	33.76	31.96	30.75	27.94	22.87	23.69	25.62	21.57	15.06
GASOLINE (%)	1.22	1.34	1.49	1.30	1.15	1.20	1.09	0.96	1.10	0.98
FUEL OIL (%)	14.58	13.84	14.22	11.72	14.11	14.94	12.91	14.05	15.17	14.09
NATURAL GAS (%)	27.39	27.00	27.98	32.00	33.53	36.19	37.04	35.50	37.51	42.78
L. P. G. (%)	0.04	0.14	0.38	0.07	0.08	0.19	0.22	0.36	0.54	0.61
ELECTRICITY (%)	24.48	23.91	23.97	24.15	23.18	24.60	25.04	23.52	24.11	26.48

K - 10*3
M - 10*6
G - 10*9

O N T A R I O   I N D U S T R I A L   E N E R G Y   S T U D Y

INDUSTRIAL STATISTICS

S I C - 365 - PETROLEUM REFINERIES

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	16	17	17	18	17	18	17	17	17	17
EMPLOYEES (#)	2,105	2,103	2,126	2,129	2,112	2,034	1,992	1,844	1,870	1,921
LABOUR COST (000$)	13,465	13,472	15,519	17,151	18,143	20,876	21,136	21,252	24,060	26,314
FUEL COST (000$)	3,336	3,629	4,267	4,574	5,286	6,001	7,649	8,291	8,916	10,447
MATERIALS (000$)	375,494	415,688	428,023	430,206	463,411	478,309	501,834	545,985	558,381	703,215
SHIPMENTS (000$)	474,909	503,473	519,719	531,546	566,224	581,699	612,384	693,117	729,369	871,166
VALUE ADDED (000$)	90,057	86,709	89,520	95,182	104,678	100,128	107,707	144,102	158,777	170,469
PRICE INDEX (1971)	849	833	836	843	860	877	904	1,000	1,026	1,171
COAL (000$)	2	2	3	1	0	0	0	0	0	0
GASOLINE (000$)	20	19	27	7	8	10	9	12	13	9
FUEL OIL (000$)	57	53	82	55	54	62	59	59	149	163
NATURAL GAS (000$)	33	45	450	511	977	1,044	1,505	1,525	1,603	2,019
L. P. G. (000$)	0	0	0	0	0	0	1	1	1	0
ELECTRICITY (000$)	3,343	3,460	3,579	3,850	4,196	4,793	5,972	6,685	7,037	8,155
OTHER (000$)	82	48	125	150	53	92	103	10	114	101
COAL (TONS)	178	208	237	86	0	0	0	0	0	0
GASOLINE (KGALS)	55	51	81	21	21	26	26	29	32	19
FUEL OIL (KGALS)	676	523	755	525	520	580	555	523	1,335	1,443
NATURAL GAS (MCF)	36	50	1,198	1,334	1,902	1,842	2,499	2,692	2,625	3,250
L. P. G. (KGALS)	0	0	0	0	1	1	2	2	2	0
ELECTRICITY (MWH)	582,693	539,823	583,771	620,666	683,363	729,759	836,341	894,761	907,419	973,988
COAL (GBTU)	4	5	6	2	0	0	0	0	0	0
GASOLINE (GBTU)	8	8	12	3	3	3	3	4	4	2
FUEL OIL (GBTU)	117	91	131	91	90	101	96	91	232	251
NATURAL GAS (GBTU)	36	50	1,198	1,334	1,902	1,842	2,499	2,692	2,625	3,250
L. P. G. (GBTU)	0	0	0	0	0	0	0	0	0	0
ELECTRICITY (GBTU)	1,988	1,841	1,991	2,117	2,331	2,489	2,853	3,052	3,096	3,323
TOTAL (GBTU)	2,153	1,995	3,338	3,547	4,326	4,435	5,451	5,839	5,957	6,826
COAL (%)	0.19	0.25	0.18	0.06	0.00	0.00	0.00	0.00	0.00	0.00
GASOLINE (%)	0.37	0.40	0.36	0.65	0.07	0.07	0.06	0.07	0.07	0.03
FUEL OIL (%)	5.43	4.56	3.92	2.57	2.08	2.28	1.76	1.56	3.89	3.68
NATURAL GAS (%)	1.67	2.51	35.89	37.61	43.97	41.53	45.84	46.10	44.07	47.61
L. P. G. (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ELECTRICITY (%)	92.34	92.28	59.65	59.68	53.88	56.12	52.34	52.27	51.97	48.68

K - 10*3
M - 10*6
G - 10*9

O N T A R I O   I N D U S T R I A L   E N E R G Y   S T U D Y

INDUSTRIAL STATISTICS

S I C - 271 - PULP AND PAPER MILLS

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	39	37	36	35	36	36	36	37	37	37
EMPLOYEES (#)	17,162	17,365	17,945	17,830	17,537	17,936	17,832	17,132	16,970	17,326
LABOUR COST (000$)	93,559	97,958	112,029	116,244	122,999	135,828	143,157	144,593	157,759	174,969
FUEL COST (000$)	38,516	39,490	41,389	43,303	44,270	48,812	53,295	58,158	61,944	67,593
MATERIALS (000$)	242,716	249,045	275,576	290,568	306,563	329,669	341,995	339,829	358,824	406,916
SHIPMENTS (000$)	560,224	574,647	622,102	627,728	649,532	715,966	732,424	728,289	778,067	932,061
VALUE ADDED (000$)	279,137	285,844	306,340	296,173	299,490	340,195	342,949	330,373	355,675	450,338
PRICE INDEX (1971)	898	904	920	941	940	970	998	1,000	1,009	1,115
COAL (000$)	9,063	8,740	9,269	10,182	9,114	7,757	6,698	5,014	4,871	3,443
GASOLINE (000$)	178	172	222	225	258	268	269	234	225	234
FUEL OIL (000$)	2,678	4,118	4,568	4,623	4,925	5,571	6,802	7,989	8,612	8,194
NATURAL GAS (000$)	8,233	7,961	7,852	8,667	9,685	11,563	12,775	15,527	17,557	21,116
L. P. G. (000$)	54	73	63	68	71	80	92	113	141	128
ELECTRICITY (000$)	17,484	17,933	18,904	18,957	19,623	22,994	26,076	28,748	30,074	34,036
OTHER (000$)	826	493	511	581	593	580	582	534	464	441
COAL (TONS)	949,189	917,644	964,845	1,040,071	861,398	704,541	569,870	326,426	294,250	207,861
GASOLINE (KGALS)	535	488	659	667	737	760	758	609	560	557
FUEL OIL (KGALS)	32,016	51,669	57,044	56,561	60,577	70,416	85,158	85,248	87,066	72,578
NATURAL GAS (MCF)	21,496	20,549	19,962	21,795	23,896	28,086	30,923	35,108	37,094	41,157
L. P. G. (KGALS)	248	323	299	322	333	375	423	549	642	515
ELECTRICITY (MWH)	3,496,570	3,564,510	3,824,797	3,693,189	3,819,208	4,022,098	3,959,071	3,968,413	4,304,856	4,233,288
COAL (GBTU)	24,223	23,418	24,622	26,542	21,982	17,979	14,543	8,330	7,509	5,304
GASOLINE (GBTU)	79	72	98	99	109	113	113	90	83	83
FUEL OIL (GBTU)	5,580	9,005	9,942	9,858	10,558	12,273	14,843	14,858	15,175	12,650
NATURAL GAS (GBTU)	21,496	20,549	19,962	21,795	23,896	28,086	30,923	35,108	37,094	41,157
L. P. G. (GBTU)	29	37	34	37	38	43	49	64	75	60
ELECTRICITY (GBTU)	11,930	12,162	13,050	12,601	13,031	13,723	13,508	13,540	14,688	14,443
TOTAL (GBTU)	63,337	65,243	67,708	70,932	69,614	72,217	73,979	71,990	74,624	73,697
COAL (%)	38.24	35.89	36.36	37.42	31.58	24.90	19.66	11.57	10.06	7.20
GASOLINE (%)	0.12	0.11	0.14	0.14	0.16	0.16	0.15	0.13	0.11	0.11
FUEL OIL (%)	8.81	13.80	14.68	13.90	15.17	16.99	20.06	20.64	20.34	17.16
NATURAL GAS (%)	33.94	31.50	29.48	30.73	34.33	38.89	41.80	48.77	49.71	55.85
L. P. G. (%)	0.05	0.06	0.05	0.05	0.05	0.06	0.07	0.09	0.10	0.08
ELECTRICITY (%)	18.84	18.64	19.27	17.76	18.72	18.00	18.26	18.81	19.68	19.60

K - 10*3
M - 10*6
G - 10*9

ONTARIO INDUSTRIAL ENERGY STUDY

INDUSTRIAL STATISTICS

S I C - - OTHER MANUFACTURING

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	9,715	9,823	10,100	10,267	10,286	10,422	10,328	10,401	10,344	10,205
EMPLOYEES (#)	335,609	355,926	384,455	380,728	373,271	386,029	374,622	370,368	387,464	408,265
LABOUR COST (000$)	1,426,963	1,580,908	1,813,950	1,894,630	1,980,778	2,217,331	2,298,330	2,437,378	2,743,297	3,132,417
FUEL COST (000$)	88,587	96,210	106,862	111,895	119,186	128,482	128,820	139,020	156,682	172,783
MATERIALS (000$)	4,156,935	4,631,579	5,366,181	5,500,926	5,726,465	6,308,092	6,330,023	6,682,633	7,491,643	8,770,838
SHIPMENTS (000$)	8,264,930	9,136,273	10,415,599	10,861,318	11,488,157	12,497,345	12,663,562	13,610,956	15,155,418	17,559,808
VALUE ADDED (000$)	4,099,161	4,528,100	5,126,850	5,314,842	5,667,946	6,283,211	6,275,485	6,775,943	7,609,570	8,841,860
PRICE INDEX (1971)	852	863	882	901	913	940	974	1,000	1,034	1,110
COAL (000$)	7,337	6,851	6,475	6,012	5,691	4,966	3,912	1,922	819	430
GASOLINE (000$)	8,812	9,597	10,782	10,601	11,361	11,750	12,127	12,788	13,025	14,289
FUEL OIL (000$)	16,529	17,969	20,064	20,542	21,439	22,197	22,031	25,183	29,058	29,089
NATURAL GAS (000$)	12,846	15,281	18,050	19,632	20,919	24,432	27,546	30,644	37,396	41,463
L. P. G. (000$)	947	1,101	1,278	1,312	1,388	1,147	889	969	1,136	1,465
ELECTRICITY (000$)	35,352	38,371	42,736	45,631	50,077	55,854	59,574	64,601	72,121	82,824
OTHER (000$)	6,760	7,128	7,480	8,165	8,311	8,135	2,794	2,909	3,131	3,237
COAL (TONS)	605,166	569,829	532,109	474,229	435,879	364,553	243,626	99,135	36,313	17,463
GASOLINE (KGALS)	24,380	25,619	28,428	27,508	27,866	27,996	28,028	29,313	29,246	29,631
FUEL OIL (KGALS)	168,504	179,760	196,655	198,292	211,491	214,738	205,672	205,776	208,678	177,099
NATURAL GAS (MCF)	17,011	20,276	23,911	25,693	27,729	33,090	38,022	41,577	51,037	54,273
L. P. G. (KGALS)	4,212	4,719	5,033	5,547	6,616	5,458	3,984	4,255	4,964	5,796
ELECTRICITY (MWH)	3,688,511	4,020,244	4,571,420	4,765,483	5,023,605	5,232,142	5,479,798	5,743,692	6,206,297	6,759,308
COAL (GBTU)	15,443	14,542	13,579	12,102	11,123	9,303	6,217	2,529	926	445
GASOLINE (GBTU)	3,637	3,822	4,241	4,104	4,157	4,177	4,181	4,373	4,363	4,420
FUEL OIL (GBTU)	29,370	31,332	34,276	34,562	36,862	37,428	35,848	35,866	36,372	30,868
NATURAL GAS (GBTU)	17,011	20,276	23,911	25,693	27,729	33,090	38,022	41,577	51,037	54,273
L. P. G. (GBTU)	492	552	588	648	774	638	466	497	580	678
ELECTRICITY (GBTU)	12,585	13,717	15,597	16,259	17,140	17,852	18,697	19,597	21,175	23,062
TOTAL (GBTU)	78,538	84,241	92,192	93,368	97,785	102,488	103,431	104,439	114,453	113,746
COAL (%)	19.66	17.26	14.73	12.96	11.37	9.08	6.01	2.42	0.81	0.39
GASOLINE (%)	4.63	4.54	4.60	4.40	4.25	4.08	4.04	4.19	3.81	3.89
FUEL OIL (%)	37.40	37.19	37.18	37.02	37.70	36.52	34.66	34.34	31.78	27.14
NATURAL GAS (%)	21.66	24.07	25.94	27.52	28.36	32.29	36.76	39.81	44.59	47.71
L. P. G. (%)	0.63	0.66	0.64	0.69	0.79	0.62	0.45	0.48	0.51	0.60
ELECTRICITY (%)	16.62	16.28	16.92	17.41	17.53	17.42	18.08	18.76	18.50	20.27

K - 10*3
M - 10*6
G - 10*9

ONTARIO INDUSTRIAL ENERGY STUDY

INDUSTRIAL STATISTICS

SIC - . - TOTAL ALL INDUSTRIES

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
ESTABLISHMENTS (#)	13,146	13,105	13,313	13,357	13,222	13,239	12,988	12,984	12,819	12,605
EMPLOYEES (#)	535,952	570,152	604,965	596,938	590,473	597,777	589,317	590,465	608,162	648,363
LABOUR COST (000$)	2,450,985	2,754,402	3,056,533	3,193,663	3,419,889	3,709,376	3,922,381	4,244,331	4,728,458	5,413,265
FUEL COST (000$)	303,778	335,137	360,956	376,167	401,551	418,999	452,856	494,819	532,421	599,097
MATERIALS (000$)	8,841,953	9,924,225	10,978,388	11,333,437	12,319,089	13,491,734	13,749,027	14,793,364	16,485,090	19,537,176
SHIPMENTS (000$)	16,616,788	18,504,423	20,239,219	21,277,035	23,080,456	24,922,528	25,408,852	27,569,503	30,526,001	36,137,015
VALUE ADDED (000$)	7,607,033	8,434,197	9,148,115	9,674,563	10,437,886	11,288,533	11,365,940	12,313,616	13,665,271	16,263,825
PRICE INDEX (1971)	1,033	1,047	1,077	1,098	1,121	1,163	1,191	1,216	1,274	1,428
COAL (000$)	47,841	52,496	53,364	52,629	47,803	37,672	35,467	31,279	22,561	18,954
GASOLINE (000$)	20,766	22,903	25,078	25,651	27,089	28,342	28,030	28,318	28,610	30,048
FUEL OIL (000$)	48,443	55,024	59,002	61,346	62,175	60,363	62,974	75,933	86,751	90,480
NATURAL GAS (000$)	43,646	49,187	56,140	63,556	74,454	85,840	103,662	118,499	136,141	157,560
L. P. G. (000$)	2,089	2,147	2,539	2,268	3,510	3,290	2,877	3,682	6,884	3,548
ELECTRICITY (000$)	122,907	135,163	145,889	152,718	168,015	184,417	207,670	226,260	241,463	279,752
OTHER (000$)	18,086	18,214	18,942	18,001	18,504	19,075	12,175	10,849	10,012	18,768
COAL (TONS)	4,562,991	4,847,068	4,876,411	4,611,444	3,992,902	3,065,167	2,308,003	1,652,557	1,235,376	954,635
GASOLINE (KGALS)	60,234	65,350	70,340	70,362	70,884	72,520	70,097	69,368	68,327	66,619
FUEL OIL (KGALS)	514,622	580,165	615,972	643,974	648,352	630,017	644,517	659,937	703,973	667,673
NATURAL GAS (MCF)	81,985	89,118	101,439	112,267	134,234	155,664	191,363	214,549	239,929	264,526
L. P. G. (KGALS)	9,598	9,572	10,876	9,937	15,990	15,339	12,805	17,575	29,349	16,000
ELECTRICITY (MWH)	18,230,963	19,822,676	21,641,672	22,409,160	24,147,152	24,613,120	26,347,915	27,123,416	27,897,104	29,325,653
COAL (GBTU)	116,447	123,697	124,446	117,684	101,898	78,223	58,900	42,173	31,526	24,362
GASOLINE (GBTU)	8,986	9,750	10,494	10,498	10,575	10,819	10,458	10,349	10,194	9,939
FUEL OIL (GBTU)	89,698	101,122	107,363	112,244	113,007	109,811	112,339	115,027	122,702	116,375
NATURAL GAS (GBTU)	81,985	89,118	101,439	112,267	134,234	155,664	191,363	214,549	239,929	264,526
L. P. G. (GBTU)	1,122	1,119	1,272	1,162	1,870	1,794	1,498	2,056	3,433	1,872
ELECTRICITY (GBTU)	62,204	67,634	73,841	76,460	82,390	83,979	89,899	92,545	95,184	100,059
TOTAL (GBTU)	360,442	392,440	418,855	430,315	443,974	440,290	464,457	476,699	502,968	517,133
COAL (%)	32.31	31.52	29.71	27.35	22.95	17.77	12.68	8.85	6.27	4.71
GASOLINE (%)	2.49	2.48	2.51	2.44	2.38	2.46	2.25	2.17	2.03	1.92
FUEL OIL (%)	24.89	25.77	25.63	26.08	25.45	24.94	24.19	24.13	24.40	22.50
NATURAL GAS (%)	22.75	22.71	24.22	26.09	30.23	35.35	41.20	45.01	47.70	51.15
L. P. G. (%)	0.31	0.29	0.30	0.27	0.42	0.41	0.32	0.43	0.68	0.36
ELECTRICITY (%)	17.26	17.23	17.63	17.77	18.56	19.07	19.36	19.41	18.92	19.35

K - 10*3
M - 10*6
G - 10*9

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